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Conference Materials of the 17th European Conference on Games Based Learning

A Conference hosted by University of Twente Enschede, Netherlands

5-6 October 2023

Edited by
Ton Spil, Guido Bruinsma
and Luuk Collou

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Proceedings of the

17th European Conference on Games Based Learning

ECGBL 2023

Hosted By

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ECGBL Preface

These proceedings represent the work of contributors to the 17th European Conference on Games Based Learning (ECGBL 2023), hosted by University of Twente, Enschede, Netherlands on 5 - 6 October 2023. The Conference Co-Chairs are Ton Spil, Guido Bruinsma from University of Twente, Behterlands, and Luuk Collou, from Saxion University for applied Sciences in Enschede, the Netherlands

ECGBL is now a well-established event on the academic research calendar and now in its 17th year the key aim remains the opportunity for participants to share ideas and meet the people who hold them. The scope of papers will ensure an interesting two days. The subjects covered illustrate the wide range of topics that fall into this important and ever-growing area of research.

The opening keynote presentation is given by Professor Sara de Freitas, on the topic of *Gamechangers: Transforming agency, engagement and communities with digital game trails.* The second day of the conference will open with an address by Jan Willem Huisman, who will talk about *The loss of Personal Play Space Undermines our Society: Playing is the Foundation for the Human Scale*.

With an initial submission of 200 abstracts, after the double blind, peer review process there are 95 Academic research papers, 6 PhD research papers, 4 Masters Research papers and 6 work-in-progress papers published in these Conference Proceedings. These papers represent research from Australia, Austria, Belgium, Brazil, Canada, China, Colombia, Denmark, England, Estonia, Finland, France, Germany, Greece, Hong Kong, India, Iran, Ireland, Israel, Italy, Japan, Malaysia, Malta, Mexico, Netherlands, New Zealand, Nigeria, Norway, Poland, Portugal, Scotland, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Tunisia, Turkey, UK, United Arab Emirates and the USA.

We hope you enjoy the conference.

Ton Spil, Guido Bruinsma and Luuk Collou

University of Twente
Enschede, Netherlands
October 2023

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Biographies

Conference and Programme Chairs

Dr. Ton Spil teaches in the area of Business Information Systems. He is track chair on e-health in main conferences and published on ISI A level. In 2021 his main topics are adoption of IT, business modeling, serious gaming and digital strategies applied on (tele)health, music, and banking.

Dr. Guido Bruinsma has built on his passion for research methodology, technology and human behavior over the years. Guido's current focus is on the development and the implementation process of game based interventions; and health, performance, and data driven systems for esports performance.

Dr. Luuk Collou finalized his PhD in 2020 at the University of Twente during which he developed and tested a simulation model and serious game for strategic human resource management (HRM). Currently Luuk is working as an associate lector for the research group strategic HRM of Saxion University for applied Sciences in Enschede, the Netherlands.

Keynote Speakers

Professor Sara de Freitas is an international author, educator and researcher with a specialism in digital technologies. With a PhD in data science, she has worked across sectors exploring how digitization and the use of digital technologies can transform lives. As a researcher and Director of Research, she has supported the foundation of the London Knowledge Lab (now UCL), established the Serious Games Institute and is currently setting up the Digital Futures Institute to push forward on the frontiers of what we know to support improved natural human computer interfaces and implement positive feedback and reward systems. In support of her theoretical studies, based on systems thinking, her field studies have focused upon quality service provision and growth in regional development. Towards that end, Sara has led academic portfolio areas in four campus-based universities, three colleges, two schools and a network of study centres in the UK, Europe and Australia, including the management and support for tens of thousands of on-campus, online and international students. Her digital strategies and systematic view of education placed her well to make huge improvements in online and edtech provision across her own and other institutions around the world.

Jan Willem Huisman, a cum laude graduate of the Art Academy in Utrecht, obtained his Master's Degree from the distinguished Royal College of Arts in London in 1996. During his academic pursuits, he developed a keen interest in the potential of interaction and the digital space to facilitate unrestricted play for individuals. Subsequently, he co-founded IJsfontein with two of his college friends, employing play as a tool to stimulate growth and development among users. IJsfontein has since evolved into a prominent studio in Europe, collaborating with numerous international universities over the past 25 years to explore the impact of games on user development and to develop effective game design strategies. Jan Willem's expertise has made him a highly sought-after international speaker, renowned for his ability to establish a pertinent relationship between theory and practice.

Mini Track Chairs

Stavroula Andreopoulos is a Professor, Teaching Stream, in the Department of Biochemistry at the University of Toronto. In 2017, she was recognized by the Faculty of Medicine for her multi-year contribution to undergraduate teaching with the Sustained Excellence and Innovation in Life Sciences Education Award.

Panagiotis Fotaris is Principal Lecturer and Course Leader for Digital Games Development at the University of Brighton, UK. He is Senior Fellow of the Higher Education Academy and has previously held positions at King's College London, University of East London, University of West London, Abertay University, and University of Macedonia. A game-based learning evangelist with a diverse background that combines computing with applied arts, games, and music, Panagiotis focuses his research on the pedagogic potential of escape rooms and immersive technology in the context of computing and design education. His current research projects include designing educational escape rooms for cybersecurity awareness training and information literacy.

Thorkild Hanghøj is a Professor of Games and Learning. He coordinates the KILD research group, Aalborg University, Copenhagen, and is also a founding member of the Board Game Collective. His work focuses on exploring links between games, dialogue, and literacies, as well as how to learn through designing games. He currently manages the research project GBL21: Game-Based Learning in the 21st Century (gbl21.dk), which explores how students learn by redesigning games within the school subjects Danish (L1), mathematics, and science.

Gunver Majgaard is an Associate Professor at the Game Development and Learning Technology Unit of the University of Southern Denmark. Since 2001, she has been teaching and conducting research at the university, leveraging her background in electrical engineering and a PhD in robots and learning, which she earned in 2011. Majgaard founded the Game Development and Learning Technology engineering program and has developed a growing interest in the use of technology to enhance learning in formal education. Her research focuses on emerging technologies in education, game-based learning, design of digital educational tools, participatory design processes, learning processes, and program and curriculum development.

Author Biographies

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Ashish Amresh is an Associate Professor in Computer Science at Northern Arizona University and does research in the development of software tools and technologies for advancing game based learning outcomes. He primarily works with build innovative game mechanics and integrating them in software frameworks as the burst game design framework and the content agnostic game engineering framework.

Mrs Evgenia Anagnostopoulou is a teacher of mathematics at ISC, University of Sussex, UK. She received her BSc in physics and MSc in astronomy from University of Sussex (1991), PGCE from Edge

Hill University (2018), and is currently doing her PhD in informatics at University of Sussex. Her main research area is game-based learning.

Dr Massimiliano Andreoletti is professor of planning and management of learning environments at the Faculty of Psychology of the Università Cattolica del Sacro Cuore of Milan. I taught Game and Animation Didactics at the Faculty of Education Sciences. His research interests concern the use of technologies for learning with particular interest in analogical and digital games.

George Andrews is a PhD student at the Open University, working on the use of Game-Based training for changing cyber security behaviour and the use of in-game assessment.

Massimo Atzori (PhD) is a lecturer on contract at the University of Cagliari where he teaches Media Education and Rehabilitation through Cinema, Performance and Television.

Hua Bai is currently pursuing a Ph.D. at the School of Informatics, Division of Game Development at the University of Skövde in Sweden. Her research focuses on visual communication in serious games.

Lorea Bailey has taught young children for 12 years, and the study presented at the conference takes place in her first-grade classroom.

Nathalie Barz is a doctoral research associate at the Faculty of Educational Sciences at Saarland University. She received her master's degree in Psychology from Saarland University in 2019 and her main research topics are self-regulated learning in university context, game-based learning, as well as attitudes towards e-learning.

Dr Gavin Baxter is a Lecturer in Computer Games Development (University of the West of Scotland). His research activities include the use of serious games for teaching and learning purposes. His interests also reside in applying serious games as an immersive approach towards informing students about 'hard' and 'soft' skill sets required for employability in the games industry.

Laleh Behjat is a professor at the University of Calgary, Canada. Her research focuses on building integrated circuits and developing innovative techniques to teach creativity in post-secondary education. She is an advocate for underrepresented groups in science and engineering and works on removing systemic barriers that exist in their advancement.

Thérèse Bergsma received her MSc degree in Human Media Interaction from the University of Twente, the Netherlands. Her interests lie in educational technology and games.

Andre Bester is a research and development engineer at the BMS Lab, University Twente. He has an M-Eng in Electronics from the University of Stellenbosch. Andre has more than 30 years' experience in sensor development, cognitive psychology research and software development. His research interests are in machine learning applied to human behaviour and serious/simulation gaming.

Mr Luke Beveridge holds an MRes in AI from the University of the West of Scotland (UWS) , UK. Luke is a PhD candidate in the UWS Creative Computing Technologies Research Group, his research focuses in applying extended realities serious games to industrial training with an interest in AI to support learning and content generation.

Jessica L. Bitter: Since her Media & Design Management, Jessica L. Bitter works as an AR developer at Hochschule RheinMain in multiple research projects about AR, interactive storytelling and serious games. The projects are focused on cultural heritage in collaboration with a popular natural science museum, and social topics respectively.

Luca Botturi holds a PhD in Communication sciences (University of Lugano). Worked in field and research projects in educational technologies in Switzerland, Italy, Canada, Spain and the USA. Currently Professor in Media in education at the Scuola universitaria professionale della Svizzera italiana (Locarno), where he researches digital and media literacy, information literacy, ad game-based learning.

Eelco Braad is a PhD-candidate focusing on applied design research in higher education. His work concerns the design of games and other digital technologies such that that learning and learners are positively affected.

Jan-Willem Bullée is a Assistant Professor of Evidence-Based Cybersecurity (University of Twente). With a background in both psychology (MSc) and computer science (MSc), he focuses on reducing cybercrime victimization. Jan-Willem's research revolves around the human element's impact, and on evaluating countermeasures such as interactive lessons programs for young learners, games for organisational staff members and easy implementable nudges

Peadar Callaghan MSc DLG is a learning game designer and instructor. He has consulted with military, government and business clients on learning game design. He is a Ph.D. candidate studying "Cybersecurity Game Design" and teaches at Tallinn University, Estonia.

Fabio Chiarello, physicist and researcher at the CNR-IFN Rome (Institute for Photonics and Nanotechnologies of the Italian National Research Council). Research: superconducting devices and detectors, quantum technologies. Outreach: conferences for high schools and public, development of didactic games and laboratories for science festivals, responsible for the "Fotonica in Gioco" Competition for Italian high school students.

Younjung Choi is a Ph.D. candidate that investigates how to facilitate a cross-disciplinary team's collaborative communication in the context of sustainability transition, at University of Twente, the Netherlands. She is interested in using artistic mediums for mediating the heterogeneous group's communication such as stories, metaphors, as well as game elements.

Long Kiu Chu is a final year undergraduate of computing at the Hong Kong Polytechnic University.

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Mária Čujdíková is a university teacher at the Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Slovakia. She received his PhD in theory of informatics education at Comenius University in 2021. In her dissertation thesis, she explores how video games can develop mathematical thinking and how pupils perceive that they encounter math when playing video games. Her main research areas are informatics education and game-based learning.

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Kelly M. Donovan is a Lecturer of English for Academic Purposes at New York University Shanghai. Her courses, "The Science of Friendship" and "The Final Boss: Defeating Social Issues in Gaming," are content-based and teach note-taking, presentation, and discussion skills. Kelly's research interests include Language & Identity, Teacher Training & Supervision, and Ludic Language Pedagogy.

Rudi Dullens (1968) is CEO of BlueTea, a Dutch company founded in 2010 developing immersive Simulations and GameBasedLearning. His career started in the 90's, educated as computer engineer.

From 1993 until 2014 he was CTO at Stepco and currently he is leading BlueTea into the innovative future of knowledge transfer and speaking at events e.g. TEDx, EuroMaintenance and company events.

Lars Elbæk is Associate Professor at the Department of Sports Sciences and Clinical Biomechanics, University of Southern Denmark. Lars does research in Didactics, Educational Technology and Higher Education. He has several years of experience in sport, physical movement, learning, and sports pedagogy. His particular interest is movement-based design methods in sport and movement entrepreneurship.

Yara Elenany received her B.Sc. degree in Civil Engineering from the American University of Sharjah. She then joined the Construction Management master's program in the same university, working part-time as a graduate teaching assistant. During her master's study, she co-authored 2 papers which were presented in international conferences. Her research interests revolve around education technology.

Sophie Fischer is a scientific assistant at the Technical University of Applied Sciences Würzburg-Schweinfurt (THWS) in Germany. In her research project and PhD, she conceptualizes educational offers to support regional companies in climate adaptation. Here, she focuses on organizational development, organizational learning, and the design and impact of leadership.

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Hillary Gould is a PhD student in Information Science & Learning Technologies at the University of Missouri with a Master of Science in Learning Technologies & Design: Online Education & Graduate Certificates in College Teaching & Serious Games & Simulation Design, primarily focused on serious game design and researching implementations of digital games for learning.

Diego Alatorre Guzmán is a designer, professor and researcher. He is currently undertaking a PhD in Contemporary Studies at Coimbra University, exploring creative education through the lens of game design. His most relevant publications include one book, multiple articles and several playful artefacts, such as the FUTURŒSCOPIO, a transmedia experience to facilitate prospective thinking.

Thomas Hainey is a Senior Lecturer and the Programme Leader of Computer Games Development at the University of the West of Scotland. Thomas has published extensively on Serious Games and Games-based Learning and runs an honours year Serious Games module. His specialisms include: assessment integration, pedagogical content integration and evaluation of Serious Games.

Thorkild Hanghøj is a Professor of Games and Learning. He coordinates the KILD research group, Aalborg University, Copenhagen, and is also a founding member of the Board Game Collective. His work focuses on exploring links between games, dialogue, and literacies, as well as how to learn through designing games.

Heidi Hautopp is an assistant professor at Research Lab: It and Learning Design, Aalborg University, Copenhagen, Denmark. Her research interests revolve around graphic and visual facilitation, design processes, play and educational games. She has a profound interest in teaching and educational development and is a member of the Board Game Collective.

Pat Healy is a serious games researcher pursuing a PhD in the University of Pittsburgh's Department of Informatics and Networked Systems. Their work explores serious game design and evaluation in primarily healthcare and education, researching video games' ability to educate, persuade, or inspire in various contexts.

Rebekka Hesser is a doctoral student at the University of Education Weingarten (Germany). She started her PhD in the science4exitschool project after completing her maths and chemistry studies for her teaching qualification. As part of this project, she creates escape games for chemistry lessons in schools.

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Ting-Chia Hsu, Distinguished Professor at National Taiwan Normal University, specializes in CT education. With 50+ publications, and visits to NIE and MIT, Dr. Hsu has had a global academic impact and serves as an editor for international journals. Ranked in the world's top 2% by Stanford scholars, she co-leads an educational big data analytics project.

Suzaan Hughes is a lecturer in the College of Business and Economics, at the University of Johannesburg. She has a keen interest in leveraging technology to enhance student learning and engagement. Her research interests include management education, strategic management and game based learning.

Giannandrea Inchingolo is a creative scientist with a PhD in physics at INAF - Arcetri Astrophysics Observatory, for which he works as a game designer and facilitator of game-based learning activities. Since 2018 he specialised in astronomy outreach and education. He is an Ordinary Member of the Game Science Research Center since 2020.

Erik Ottar Jensen is a Ph.D.-student at Aalborg University. His academic background is technology in education with focus on mathematics education. His main research interests are use of digital technologies, games, programming and design approaches in classroom teaching and dialogical approaches to learning - including how commercial games can be used for educational purposes.

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Jana Kalb is a research assistant in the project Tierschutz erLeben at Rhine-Waal University of Applied Sciences in Germany. She is a veterinarian and also deals with knowledge transfer in animal welfare in her dissertation project at Justus Liebig University. She provides the content related to animal welfare and coordinates.

Michael Kickmeier-Rust is a Professor of Psychology at the University of Teacher Education St. Gallen, Switzerland. He holds a PhD in Cognitive Psychology and has a strong technical background as software developer. His research focuses on pedagogical diagnostics, smart embedded competence assessment as well as serious games and game-based assessment and training.

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Chih-Chen Kuo is a doctoral student of Mini Educational Game Development Group, Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taiwan. Main research areas: applying gamification and game-based learning in Digital Humanities. She is also a woman entrepreneur applying gamification to help organizations struggling with effective advocacy to arise people fulfil SDGs issue in life.

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Vanessa Lawrence is the Instructional Services Librarian at New York University Shanghai. She supports information literacy development in core curriculum courses by providing in-class workshops, online modules, and one-on-one student consultations. Vanessa's interests include information literacy instruction, conceptions of academic research, open access, and integrating game-based learning into library outreach and instruction.

Sarah Lukas is a Junior-Professor of Psychology as well as Deputy Director of the Research Centre for Secondary Education at the University of Education Weingarten (Germany). She is one of the leaders of the project Science 4 Exit. Her main areas of research are digital literacy, foreign language learning as well as innovative learning environments.

Mr. Yujun Ma is a graduate of the Computing Department at Hong Kong Polytechnic University. He is primarily responsible for game design and development in the team. He has been recognized in several creative and technological competitions in Hong Kong and internationally and focuses on emerging XR technologies to create immersive educational experience.

Katerina Roubidou is a professor of Computer Science at 1st Vocational School of Kamatero. She graduated from the Information Technology dept. the Alexander Technological Educational University of Thessaloniki in 2000 and speaks English and French. She has been teaching in secondary education since 2002 and for a lot of years up to now she is either participating or organizing school activities

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Dr Emanuela Marchetti is associate professor at the University of Southern Denmark (SDU), Kolding campus. She has a master in interaction design from the University of Southern Denmark and a PhD from Aalborg University. Her main research areas are e-learning, interaction design and Computational Thinking, with a playful sociomaterial perspective.

Edgar Paul Martinez Ludert Muñoz de Cote is a Mexican artist and visual designer with a master degree in Industrial design at UNAM and the University of the Arts (UDK). Director of Design - professor at Tecnológico de Monterrey. His current research avenues are arts in education and life centered design.

Asge Matthiesen is a PhD student at the University of Southern Denmark. He has been teaching in a couple of years in various subjects but mostly regarding learning technology. He holds a master's in engineering and his main research areas are, among others, virtual reality, health technology, learning technology and health innovation.

Georgia Mavroudaki teaches History at the Vocational School of Kamatero. She graduated from the Department of Archaeologists and History of Arts at Athens University and worked as an archaeologist for five years. She has a master's degree in Rhetoric: Theory and Practice from the Primary School Department of Kapodistrian University of Athens in 2022.

Yantao Meng. I'm from China, and I'm currently studying at Toyo University in Japan. I primarily use Unreal Engine for various research and game production. This is my first time presenting my research topic at an international conference. Thank you in advance.

Ms. Ines Miguel-Alonso is a PhD student at the Faculty of Humanities and Communication at the University of Burgos (Spain). Her research focuses on the development and enhancement of Virtual Reality simulators for education and industry. She has a background in Computer Science and passion for exploring the potential of immersive technologies in various fields.

David Moffat is a lecturer in serious games design, who develops methods of design that incorporate the motivation and cognitive states of the player. He has conducted research into using games to teach young children to program, and organises game-jam events for primary schools.

Jenny Moffett is a faculty developer at RCSI University of Medicine and Health Sciences. She is past Director of Communication Skills at RUSVM, St. Kitts, and Programme Director at the School of Veterinary Medicine, Surrey, UK. Jenny is a PhD candidate at Utrecht University exploring how digital escape rooms can facilitate learning in medical education.

Dr. Noor Asmina Binti Mohd Rashid was born on 7th November 1989 in Marang, Terengganu, Malaysia. She holds a Doctorate Degree in November 2022 from Universiti Teknologi Malaysia and started her career as a lecturer in the field of Educational Technology at UNITAR International University, Malaysia in April 2023.

Peter Mozelius is an Associate Professor and Researcher, working at the Department of Communication, Quality Management and Information Systems at the Mid Sweden University in Östersund, Sweden. His research interests are in the fields of Game-based learning, Lifelong learning and Programming education.

Lorena Müller is a game designer and -developer working for the research project “AusWege” at Hochschule RheinMain, Germany, which is developing digital serious games on the topic of Intimate Partner Violence (IPV).

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Subhangi Namburi has a Master’s degree in Human Computer Interaction and a Bachelors degree in Liberal Arts with a concentration in Psychology and Anthropology. She works in the field of education and public health research, and intervention development. She builds toys, works in theatrical productions, and aims to bridge the gap between the sciences and the humanities.

Muthu Kumar Narayan is an information technology professional working in Cognizant Technologies in Chennai. He is a Consultant at Intellect Arena, which was instrumental in working on physical and mental well-being for children in US and India. He supported the online programme for Indian Diaspora children engaging with chess during the pandemic time.

Tobiasz Naryniecki is a Ph.D. candidate in psychology at the University of Warsaw under the supervision of Ph.D. Mirosława Huflejt-Łukasik. Holder of a postgraduate degree in 'Entrepreneurial and Intrapreneurial Project Management' from Sorbonne. Researching the reactions to game-based assessments, conducting both quantitative and qualitative research in collaboration with organizations that use games in their recruitment processes.

Dr. Smart Olugbeko is a Chief Lecturer at Adeyemi College of Education, Ondo, Nigeria. He received his PhD in Education (Reading Strategies) from Staffordshire University, Stoke-on-Trent, United Kingdom in 2018. His main research areas are reading strategies, curriculum development, professionalisation of teaching.

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Sónia Pais, PhD in Education, is an Associate Professor at the Polytechnic of Leiria. She is a researcher at CiTUR - Centre for Tourism Research, Development and Innovation. Her research interests are in educational sphere, including how best to teach math subjects. She has interest in Mathematical Education, Educational Technology, Pedagogical Innovation and Game Based Learning.

Marcus Vinicius Pereira Pessoa. Marcus is Assistant Professor in Engineering Management at the University of Twente’s Systems Engineering and Multidisciplinary Design Chair. His research interests are Systems Modelling and Architecting using MBSE and Program Management. Before becoming an academic, Marcus was a program manager, systems engineer and a pilot in the Brazilian Air Force, where he was responsible for the development and acquisition of air defence and aerospace control systems.

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Chiara Piazzalunga is a PhD student at NearLab, Politecnico di Milano since November 2021. She obtained her Master's Degree in Computer Science and Engineering at Politecnico di Milano in2020. The objective of her research is to design and develop novel methods for early detection of Specific Learning Disorders in children, especially through serious games.

David Prihoda is from Olathe, Kansas. He received his BA and MA from Ottawa University and Emporia State University, respectively. He has taught English and writing in Kansas, as well as abroad in Malaysia with the Fulbright Program. David currently teaches English at Ottawa University whilst also pursuing his PhD at Old Dominion University.

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Andrés Felipe Reyes has been a cognitive neuroscience professor in Colombia since 2010. He completed his postgraduate studies at the University of Potsdam in 2009. His main area of research is the cognitive neuroscience of language, and he is passionate about university teaching.

Margarida Romero is a full professor at Université Côte d'Azur (France) and an associate professor at Université Laval (Canada). Her research is oriented towards the inclusive, humanistic, and creative uses of technologies (co-design, game design, robotics, and creative uses of AI in education) for the development of creativity, problem solving, collaboration, and computational thinking.

Xavier Rubio-Campillo is the Group Leader of DIDPATRI (Heritage & Learning) and a Ramón y Cajal tenure-track fellow at the University of Barcelona where he explores how interdisciplinary approaches integrating Humanities and Computer Science can promote critical perspectives on the challenges faced by past and current societies

Isabel Rubner is professor for chemistry and its didactics at the University of Education Weingarten (Germany) and leader of the project Science4Exit. Her research focuses on curricular innovation research, digitalization, development of innovative teaching and learning materials, and innovative concepts for teacher training and continuing education.

Valérie Sallaz is a university professor and independent educational designer. She has worked for many years as a serious game designer for large companies. As a teacher, she leads a reflection on the use of serious games in the classroom, particularly in the field of management.

Lisa Sällvin is a doctoral student in information systems at the Department of Communication, Quality Management and Information Systems at Mid Sweden University. Research interests include Maker culture, Inclusive design, STEM education, and Game-based learning.

Ms Anjuman Shaheen: PhD student of computing, engineering and mathematics at the University of Brighton, UK. She has been working in game design and development for over 10 years and remained engaged with multiple projects, mainly education, people's wellbeing, and entertainment. Currently, PhD research is developing Reflective game design principles to improve self-regulatory behaviour for game-based learning.

Martin Sillaots is an associate professor of serious games and the head of the Digital Learning Games master's programme (http://dlg.tlu.ee/) at Tallinn University. He teaches courses like Agile Project

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Dr. Luana Silveri is a Ph.D. researcher (Free university of Bozen). IT,Biology, and chemistry teacher (Scientific Gymnasium, Cavalese, IT). An ecologist with ten years' experience in climate change and Alpine freshwater ecosystem. Now a researcher in game-based learning for STEM, game jams for green skills and particularly system thinking. Passionate gamer and game designer for educational games.

Ana Elisa Sousa, PhD in Sociology, is Invited Associate Professor at the Polytechnic of Leiria and a researcher at CiTUR- Centre for Tourism Research, Development and Innovation. She has developed research in the areas of Tourism, Hospitality, Digital Marketing, Pedagogical Innovation and Information and Communication Technologies.

Carla Sousa is a PhD in Communication Sciences from Lusófona University, where she also took a Bachelor's Degree in Psychology and a Master's Degree in Clinical and Health Psychology. Her main research targets are the different intersections between media, with a particular focus on games, inclusion, learning, behavior, and human diversity.

Dr. phil. Christian Stein is a Germanist and computer scientist. As Co-Founder of gamelab.berlin he conceptualized and developed numerous games for scientific applications, museums and teaching (http://gamelab.berlin). He currently works in the Excellence Cluster Matters of Activity at Humboldt University Berlin and leads the project Object Space Agency which is creating experimental Virtual Reality exhibitions.

Ian Stewart is a Reader in Project Management Education, in the Department of Engineering Management at the University of Manchester. He also teaches at University of Warwick and Paris Sciences et Lettres. He has created and used a range of games and simulations in his teaching practice, in classes of up to 500 students.

Oksana Strutynska is a full professor of the department of IT and programming in Dragomanov Ukrainian State University (Kyiv, Ukraine). She is academic coordinator of the Erasmus+ Jean Monnet Module in STREAM education (2022-2025). Her main research areas are computer science education, educational robotics and STEAM education.

Rebecca Sutton is a Canadian lawyer based at the University of Glasgow as a Senior Lecturer in International Law. She holds a PhD in Law from the London School of Economics. Her research interests include: international humanitarian law, law and emotions, socio-legal methodology, youth peacebuilding, and the use of games for legal pedagogy.

Georgios Thoma is a PhD student in Loughborough University, UK. With an undergraduate degree in mathematics, MA in mathematics education—and after a couple years of teaching secondary school mathematics—he now examines fractions through video games (and vice versa).

Merve Tillem graduated from Istanbul Bilgi University's Architecture Department in 2019. She is currently pursuing a Master's degree in Game and Interaction Technologies at Istanbul Technical University. Additionally, she works as a Product Designer at Digital Turbine company.

Chiara Trevisan: Senior researcher (Institute of Tropical Medicine, Ghent University, Belgium). Received PhD in Epidemiology and Public Health (University of Copenhagen, Denmark, 2017). Has a multidisciplinary profile in epidemiology, disease burden, health education and One Health. Primary

research interests relate to the prevention and control of neglected tropical diseases, particularly in designing and evaluating novel control/intervention tools."

Athanasios Tsionas received a bachelor degree in Informatics from the Aristotle University of Thessaloniki, Greece, in 2020. He did his traineeship at the European Medicines Agency Amsterdam as data analyst for 10 months. Currently he is student at the MSc in Artificial Intelligence and Data Analytics, Department of Applied Informatics, University of Macedonia, Thessaloniki, Greece.

Dr Andrea Valente is associate professor at the University of Southern Denmark, (SDU) Kolding campus. He has a master in computer science, with specialization in computer graphics and formal methods. He received his PhD at Torino University (Italy) about formal languages and type systems. He currently works on web technologies, e-learning and Computational Thinking.

Robby van Delden Dr. is an assistant professor at HMI at the University of Twente. He received an MSc in HMI and IDE. His PhD was on "(Steering) Interactive Play Behavior". His research combines embodied interaction with entertainment computing including sportification, co-design, sports, health, and learning; teaches Game Design, Interactive Media, Experience Design and HCI.

Dr Peter Vankúš is a university teacher at the Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Slovakia. He received his PhD in theory of mathematics education at Comenius University in 2002. His main research areas are game-based learning, mathematics related beliefs and attitudes and study of pre-service mathematics teachers beliefs.

Paul Varney is a research assistant at Cologne Cobots Lab and Cologne TrainING Center at TH Köln/University of Applied Sciences. As an educational scientist with a background in communication and information sciences, he works interdisciplinary in the field of game-based learning and mixed-reality learning environments in engineering education.

Professor David Vizcaíno Bedrán is a Spanish teacher at the Tecnológico de Monterrey. He is Mexican, he has an undergraduate degree in Hispanic Literature from Universidad de Sonora, Universidad de Granada, and Universidad Nacional de Córdoba. Passionate about teaching for almost 10 years, he always looks for ways to innovate.

Naomi Wahls is a Learning Developer at TU Delft in the Netherlands. Her two Masters are in Information and Learning Technologies and Spanish from the University of Colorado Denver in the USA. She has been supporting online higher education since 2006. Her research topics are virtual exchanges, learner engagement, and educational tooling.

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Discovering Educational Game Design Through 'Conversation Starters': Teachers' and Game Designers' Perspectives

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Abstract: Educational game (EG) design process has its complexities which are recognised differently at player-end. The need to understand teachers' perspectives and views about identifying what makes games educational (whether they use or prefer EGs or digital games), the problems and barriers encountered in their practice while using EGs, any design challenges that hinder their use and the 'pains and gains' of using EGs in their classroom is crucial. In parallel, these inquiries should also be investigated from game designers' perspectives to visualize both stakeholders' needs. Therefore, this paper presents the data of six teachers' and six game designers' views during the co-discovering design thinking workshop method on the above inquiries, based in the Australian context. This paper presents the first co-discovering technique called the 'conversation starters', where both stakeholders discussed their current practices relevant to EGs along with the probes listed above. The data is thematically categorized, coded, and analysed using NVivo. The results are presented through the constructivism paradigm, which is grounded by theory of experience (Dewey, 1938) and the participatory design method. The intentions are to provide insights for game designers in designing EGs, this can enable teachers and game designers designing EGs towards understanding some issues and expectations from teachers to help their designing process of EGs.

Keywords: Educational game designing, Conversations, Empathy, Design challenges, Barriers and problem in design, Games in classroom, Use of games, Educational game design

1. Introduction and Relevant Literature

Playing games for learning is known as an entertainment, but it also facilitates teaching depending on the situation (Gee, 2003, Gee, 2007). Games are identified as highly motivating and engaging tools for 21st-century skills and the tech-savvy generation. The mastery of new challenges, the methodology of trial and error, the repetition of a task to better understand concepts – all demonstrate positive learning through games (Barab et al., 2012, Squire and Barab, 2004, Young et al., 2012). However, the binding elements of game design in educational learning results support positive and negative results (Young et al., 2012). The GUMC model, which allows teachers to use games in classrooms to explore in a useful way, covers detailed barriers faced by teachers in classrooms (Stieler-Hunt and Jones, 2015a, Stieler-Hunt and Jones, 2015b). Perhaps it indicates the emphasis on allowing game designers and teachers to design games together, which may cover some obstacles such as insufficient time in school (Kirriemuir and McFarlane, 2003), or how games are aligned with their learning/thinking in parallel with the course (Stieler-Hunt and Jones, 2015a). Other researchers showed how the gap between teachers' learning and the use of games in their classroom produces innovatively different learning experiences, and therefore pedagogical approaches need to be addressed alongside students' learning experiences.

Recent studies have highlighted the importance of students' perceptions and teachers in classrooms. The studies include perspectives on the learning environment, engagement strategies, teacher motivation strategies or even the comparison of students' and teachers' perceptions in the classroom context. The differences in the views of students and teachers about a learning environment are vast. This requires the researchers to pay detailed attention to critical analyses and position teachers and students as important actors in a learning environment(Könings et al., 2014). A study investigated how primary school children react to the inclusion and exclusion of their peers during game play in NSW (Australia) through observation and interaction interviews (Varea and Ndhlovu, 2017). The results indicate that the use of exclusions allows students to maintain their friendship (social aspects) and that the strategies adopted by adults to promote inclusion among children vary depending on the choice of play.

Acknowledging the way Gee (2004) has observed games as a situational context or learning environment, it is unclear how the proposed principles can be standardised in a gaming practice or at game design level (Linderoth, 2012). It is crucial to emphasize the importance of the learning experience the player has, while addressing the variety of their experiences. Understanding players' motivational and engagement levels along with the acquisition of the subject matter while playing has been challenging to assess. Adams & Clark (2014) argue that as players act in educational physics games, they also need to conduct a self-explanation task through a pedagogical agent. However, this has yet to demonstrate any significant effect on learning outcomes (Adams and Clark, 2014).

Globally, many EGs have been created or produced, but only a limited number of them have emerged within the gaming industry (Hamdaoui et al., 2019). Numerous reasons could justify this (Gunter et al., 2008, Kim et al., 2017):

- EGs do not provide an optimal balance between educational content and gameplay,
- The combined value of gameplay and learning content is mismatched (focus on quality of design - the looks – rather than the learning),
- Lack of involvement of teachers and educators in the process of designing,
- Overly prioritizing the seriousness (learning content) and reducing the fun element, which leads to demotivated players.

For instance, Magnussen et al. (2003) applied PD as an approach to design, develop, and evaluate the game development process, where the participants were children (age 11-12) as designers of the game concept, and the teachers presented the game concept. Moreover, they reported opposing interests as a result: while children are crucial in designing and developing games for education purposes and the PD approach enabled teachers to gain a deeper understanding of their students' perceptions, teachers were not supportive of the idea because they believed that children could not fully understand the educational goal(Magnussen et al., 2003). Similarly, Könings, K. D. et. al (2011) examined whether the PD approach could potentially reduce misunderstanding and incongruences between student perception and teacher instructions (Könings et al., 2011), and suggested positive outcomes for education, as teacher-student disagreements and perceived discrepancies were collaboratively acknowledged. Moreover, another study reported the need to bridge serious games and PD to explore the possibilities of existing players' knowledge and use co-designing methods to achieve serious game goals (Khaled and Vasalou, 2014). Khaled and Vasalou (2014) involved three children (age 10) for the workshop sessions and reported a mixture of outcomes: creative ideation processes, freedom of choice to build upon, being unaware of conflicts between one another, sharing and learning to maximize the chances of design choices of the game, and the quote "Teachers are strict, and the game will not be fun" (Khaled & Vasalou, 2014, p.6). Könings et al., (2007) work further extended to combining the perspectives of designers, teachers, and students by proposing a Combination-Of-Perspectives (COOP) model (Könings et al., 2005), that acknowledges the importance of the different stakeholders involved: instructional designers (instructional materials and educational approaches for learning environment), teachers (building/creating appealing learning environment), and students (their perception and influence of the learning environment and quality of learning outcomes).

With the gaps and issues addressed above, this paper intends to provide a broad idea of what teachers and game designers have in common or differences in opinions about the EG design, the designing processes, and playing EGs before using in the classroom. Teachers are the initial players of EGs before the game is introduced within the classroom. Hence, their involvement in discussion may help identify the gaps between both teaching and game-designing industry is at large.

2. Theoretical, Conceptual, and Methodological Approach

The conceptual and theoretical framework adopted in this paper relates to Dewey's theory of experience (1938): growth of experience, purpose, and continuity. As these concepts were relevant to the epistemology and ontology of the research, constructivism belief is situated as the paradigm to allow the construction of new knowledge which welcomes the subjectivity of individual experiences (Dewey, 1938). The growth of experience represents how individuals grow in their career, experience the everyday activities to gain knowledge, learn to achieve their goals, sustain their understanding of the phenomenon, and continue to grow in their experience. The aspects of 'growth' are driven by one's desire to formulate a 'purpose' that reverts to the growth of experience with the intelligence of one's mind. In this context, the adults whose learning methods combine work and studying, or theoretical and practical exposures are highly familiar and productive in their expertise. *The purpose* is simple when a desirable quality *"…which identifies freedom with power to frame purposes and to execute or carry into effect purposes so framed. Such freedom is, in turn, identical with self-control; for the formation of purposes and the organization of means them are the work of intelligence"* (Dewey 1938, p.67). Dewey's description of an actual purpose is that it begins with an impulse. It is always equipped with *"end-view" – which is involving "the foresight of the consequences that may result from acting upon that impulse"* (p.67). Teachers create their meaning and reflect through their actions constantly as the games are played or play tested while game designers have similar ideals. Hence, deriving an enriched experience shows an individualized aspect of learning by playing games, learning by doing, and adapting the experience throughout the process.

The principle of *Continuity* is each experience taken from the past affects the future experience of the individual. In contrast, interaction is referred to the situational and teacher's influence on student's experience. He believes that the elements of interaction and situation in which they occur are *"inseparable from each other"* (1983, p. 41). Despite the importance of experience, some challenges may encounter, such as *"that all experiences are genuinely or equally educative"* (1938, p.13). Hence, the teachers must first comprehend the nature of human experience, stating that the effect judges the experience's value that this experience has on the individual's present and future, an individual's ability to contribute to society. This is placed directly to the idea of how teachers interact in their classrooms with every individual's needs, to be able to support their cultural and social differences, and to allow them to learn equally and freely. Similarly, game designers empathise and understand the experiences of players, designers, and also game designing processes to help design educational game design experiences. It is, therefore, crucial to position the commutative experiences of teachers and game designers to understand their perspectives, which may be enjoyable, may not contribute to personal growth or experience with no coherence to a situation that does not necessarily result in a cumulative learning foundation for future learning.

3. Data Collection, Analysis, and Interpretation Approach

As the participatory design research enables the co-discovery and co-construction of knowledge between experts, this paper reports the variations of ideas thoughts and reasons that allows various participants' experience to unfold (Muller et al., 1993). As this paper reports part of a project, the data collection presented is categorized under T (Tiny, 2-4 participants per session) group, as the best possible category during COVID-19. CODWs were conducted via Zoom video-conferencing software. The Co-design workshops (3 different groups) were audio-visual data recorded, transcribed, and time stamped. An initial hand-coding approach was adopted prior to an in-depth thematic analysis using NVivo 10 Software. The data was collected as 'audio-visual' (audio and video recording) materials to provide data fidelity through to the transcription phase of data analysis. The participatory observation requires the researcher to engage in the participants' activities and record systematic observations (Leavy, 2022). The details are shown below:

- The data is an audio discussion and video recorded (screen recording) and hand-written (memo and note-taking). It is transcribed later based on each group of co-design workshops.
- Tangible sheets (from MURAL[1])
- The researcher's observations and video recording (screen-recording) of the co-constructing of the activities.

This research adopted a six step thematic analysis approach (Braun and Clarke, 2006, Braun and Clarke, 2012). This analysis aims to allow teachers' perspectives, inspirational and motivational drivers, their experience (its growth & continuity), and the way they evaluation the games/EGs before they are used in the classroom to emerge (framing the purpose of using games as a learning tool). The themes are discussed through interpretivism approach where hermeneutic analysis is adopted to allow the subjectivity of both stakeholders' experience to flow through the experience, education, the perspectives of using games in the classroom, and how they select the games - correlating and critically discussed through researchers' epistemology and ontology position as well as concepts of the theory of experience.

Overall, there were six primary school teachers, and six game designers who participated in the co-designing method. All participants were based in Australia, specifically, in Melbourne Victoria. In the results section, the participants are addressed as teachers [T_1, T_2 etc] and game designers [GD_1, GD_2 etc]. See Figure 1 to visualize the process of positioning both stakeholders in the empathy and conversational position.

[1]MURAL is "a space for your team to collaborate visually and problem-solve faster with an easy-to-use digital canvas. No ordinary online whiteboard, MURAL has powerful facilitation features, guided methods, and the deep expertise organizations need to transform teamwork." (Direct link: https://www.mural.co/)

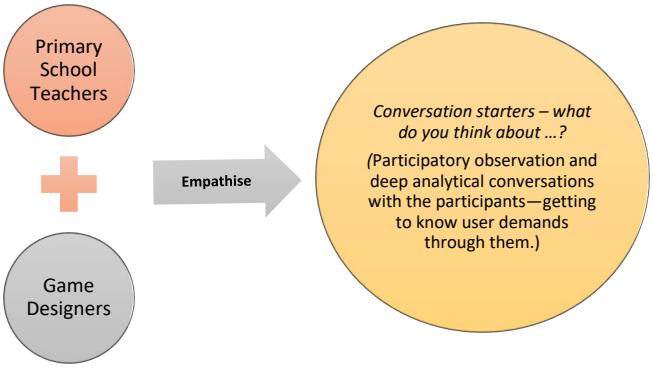

Figure 1: Illustrates the conversation started activity and how empathy is positioned to enable co-discovery aspect

4. Results and Discussion

Conversation Starters is an activity that is known as a warm-up discussion were free flowing of sharing perspectives and ideas quickly. This activity is 10 minutes in duration, and it is focused on specific questions such as "*What you think about…?*" to begin ideation on EGs, and focus on what participants exemplify, identify, or criticize about EGs that they have used or designed. This activity is designed to help participants focus on their tacit knowledge and opinions without hesitation. The objective of this activity is to encourage creativity and outside-the-box thinking from the participants. Please note that due to limitation, this paper present most crucial ideas and quotes.

4.1 Prompt Questions 1: Identify What Makes Games 'Educational'?

Both GDs and teachers drew upon their expert opinions on EG design. The question was, "*Identify what makes a game 'educational'?"* empowered both teachers and GDs felt at ease to freely generate ideas and drop them quickly through the conversation. All six participants' responses were thematically analysed, which revealed themes including problems/barriers, design challenges (for GDs and teachers), using different games that were not entirely designed for 'classroom context,' and teaching challenges (that teachers encountered) associated with the use of the game in the classroom.

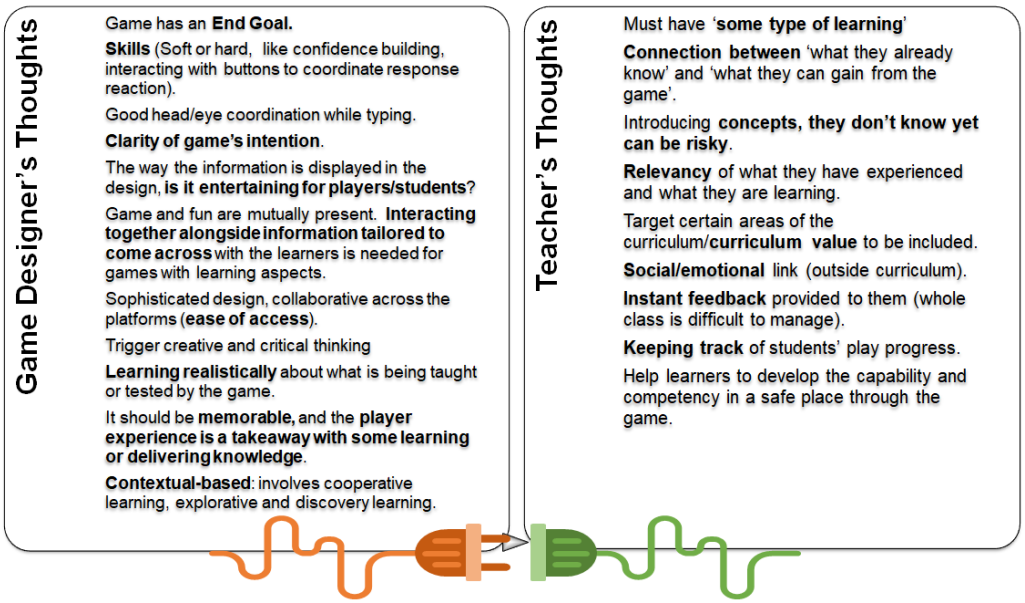

Figure 2: Currates and presents categories and qoutes from all participants: *what makes EGs?*

Figure 2 shows the data transcribed from both participant groups on *what makes games Educational?* I observed a diverse range of similarities and distinctive thoughts shared. To summarize the results, GDs described that an EG need a clear goal and set of intentions to help guide the learners/players as they play. They emphasized that EGs enable learners' soft and hard skills through gameplay and asserted that designing such gameplay requires them to understand their players' curiosity, surprising elements, clarity in communicating the game goals (game

aesthetics and realistic design) and interactivity of game designing to deliver expectations. In addition, participants asserted the need to design EGs that can be accessible on multiple platforms, to enable ease of use (for both teachers and students) and encourage collaboration to ensure that students play experience are memorable and meaningful. Interaction provides various ways of communicating and triggering a player's reaction as they interact with the game design (Schell, 2008). Hence, the interaction between the game's goals, the functionality of the game, and how these connect are highly essential, as GD participants suggested: [GD_2] "*… together alongside the information tailored to come across with the learners is needed for games with learning aspects*". Although GDs did not explain what they mean by learning aspects, [GD_3]:

> "It is mainly the learning content, the information that we game designers are trying to convey through the game design... it is not essays for players to read because that is not fun, but it is something that is crucial for EGs and students to grasp the goals and achieve rewards."

Based on Figure 2, teachers emphasized the need to have consistency between the topic taught in the classroom and the topic/game content explored within the EGs. They associated this with the challenge that if students can't relate their prior knowledge with what the gameplay contains, the students will fail in achieving the goal. Teachers also asserted that it impacts the students' play experience, interaction, and memorable experiences of gameplay. Similar with GDs, teachers believe that it is crucial to maintain consistency between content shared and learned by the students. They believed that introducing a game with no relevant concept *prior* to play experience may be risky and lead to confusion or demotivation for players. Teachers asserted the need for EGs to enable learners with developing their capabilities, competencies, and skills through gameplay, which is like GDs' observations on context-based game design. For teachers, learners can take actions within the game environment and not physically harm another peer, while game designers explained that the game design should cater to the needs of expectations from a classroom teacher to allow such context to be formed.

Particularly, all teachers emphasized that EGs should focus on curriculum values and learning skills within the game itself to help learners relate to the curriculum, topic, or subject. Teachers emphasized that they playtest all EGs before introducing in the classroom. In addition, teachers advocated that EG design should have a social and emotional link that immerses learners to gain emotional experiences such as excitement, failing, winning, or winning competitively; all contribute towards engaging and learning through experiencing. 'Good games' were the term used by the teachers indicated that games with clear learning goals, assessment or checklist and an interactive design. Teachers repeatedly emphasized that mostly, good games, which they consider fun and engaging for their students, rarely have progress or goal achieving bars. This hinders teachers' practice as they cannot track the progress of their students individually. I observed that teachers highly recommended the need to have tracking or progress bars in the game design to enable their practice into collecting each students' play-progress as "*monitoring 25-30 students is not easy during game playing*" [T_2]. Lastly, they added that instant feedback within the game is crucial, but if the feedback does not scaffold or guide the players on what they have done correctly or wrongly, it is meaningless.

Figure 3 (below) presents the data from both participant groups with respect to problems/ barriers/ challenges encountered during their identification of EGs design processes. Teachers acknowledged their concerns are more relevant to the way game levels are designed, and it's an issue when game levels do not match students' intellectual growth levels, or the interactivity is not suitable for learners. Relatively, teachers asserted that EGs should have functions that could cater to versatile learning abilities such as reading aloud, sounds and inclusive designs – to support teachers in ensuring that EGs can assist their learners' capabilities. Moreover, teachers advocated that most EGs assume that learners have prior knowledge and do not scaffold instructions or guidelines. This issue hinders the learning process of learners and teachers require more time to scaffold the instructions within the game. Consequently, teachers considered these questions (see quotes) and thought there was a possibility for such links:

> *"linking between what their [players] current experiences are with the abilities to progress at their levels of intellectual development [T_2]"*

> *"does it need to set levels that we as teachers must adhere to?[T_1]"*

These concerns are thought-provoking, and all three teachers conveyed common barriers and challenges that they encounter with EGs in the classroom. Teachers' continuous interaction with games reconstructs their experience and enables a better understanding on the way they learn about their learners' reactions while gameplaying. Intriguingly, some points from GDs surprisingly pondered similar concerns.

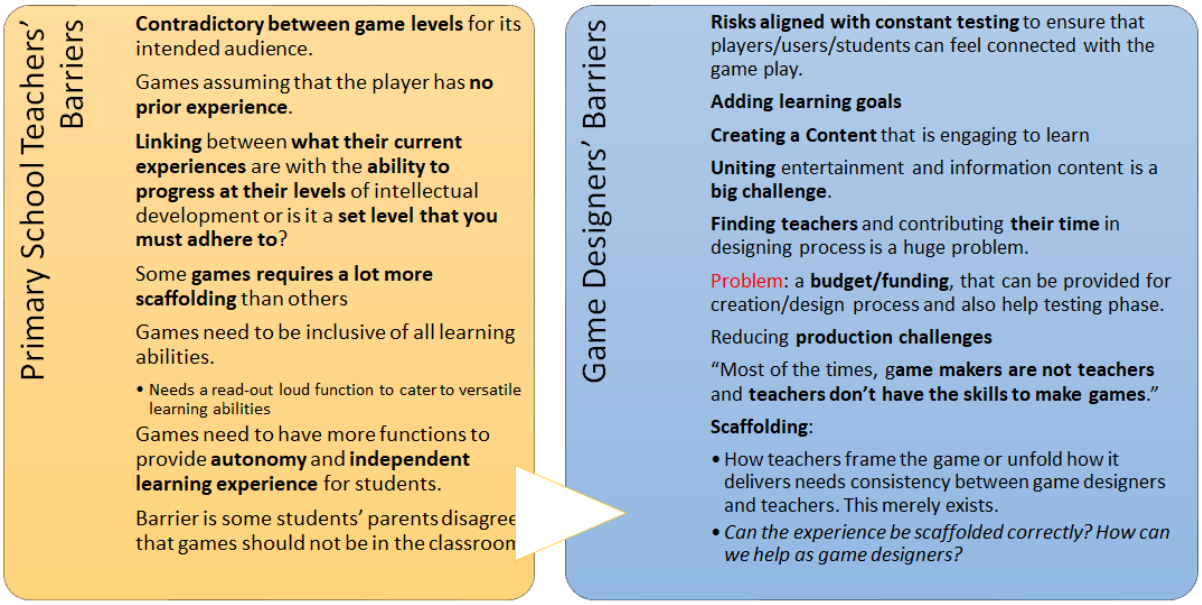

Figure 3: Summarizes and presents quotes/categories from all participants: Problems/Barriers

GDs participants shared stimulating questions including:

> *"Can the experience be scaffolded? How can we help as game designers? [GD_1]"*

> *"How teachers frame the game or unfold how it delivers needs consistency between game designers and teachers as this [rarely?] exists! [GD_3]"*

These questions are relevant to what teachers emphasized as the scaffolding needs of the games. GDs addressed the crucial concern that:

> *"most of the time, game makers are not teachers, and teachers do not have the skills to make games [GD_2]."*

This causes difficulties with the way the game is designed to be used as opposed to the way the game may be used. Despite these barriers being emphasized, GDs discussed three other crucial points.

- Firstly, adding learning goals without teachers is challenging and gathering insights from teachers in designing process relies upon funding, time limitation and teachers' availabilities.
- Secondly finding teachers to participate in the design process is a challenge, for instance: "*creating learning content that is engaging to learn is confronting to my knowledge of designing games [GD_5]*".
- Thirdly is an identified gaming industry challenge: that the reduction of production costs, the lack of resources and experts in the field, and lack of playtesting for design leads to constant risks in achieving the game goals and meeting the players' expectations. The way GDs framed their *purpose* is based on their desires to design an EG that reaches and satisfies a large population of gamers (Dewey, 1938). However, with these challenges and barriers, their best option resides in researching and evaluating their play experiences (past, present, and iterative playtesting) of playing good or bad EGs/games; and ensuring that failing mechanics or a flawed player's experience in a game is not repeated (reflective and experiential learning).

Figure 4 presents the emerging ideas discussed by teachers and GDs in terms of the game design challenges. Both participant groups encountered design challenges in their practice, and this theme potentially explains the essentialness of collaborative intervention between multiple stakeholders. As mentioned earlier, teachers' concerns with the lack of scaffolding within the game designs that requires extra time prior and during the lesson was prominently highlighted by all teachers. Teachers rely on their play experience and empathise with their learners' play experience and tend to believe that trial-and-error playing of various games can enable a better understanding of their learners' expectations. In addition to that, teachers asserted the need to clearly present learning goals, rewards and reduce text-based content within the design to avoid demotivation by learners.

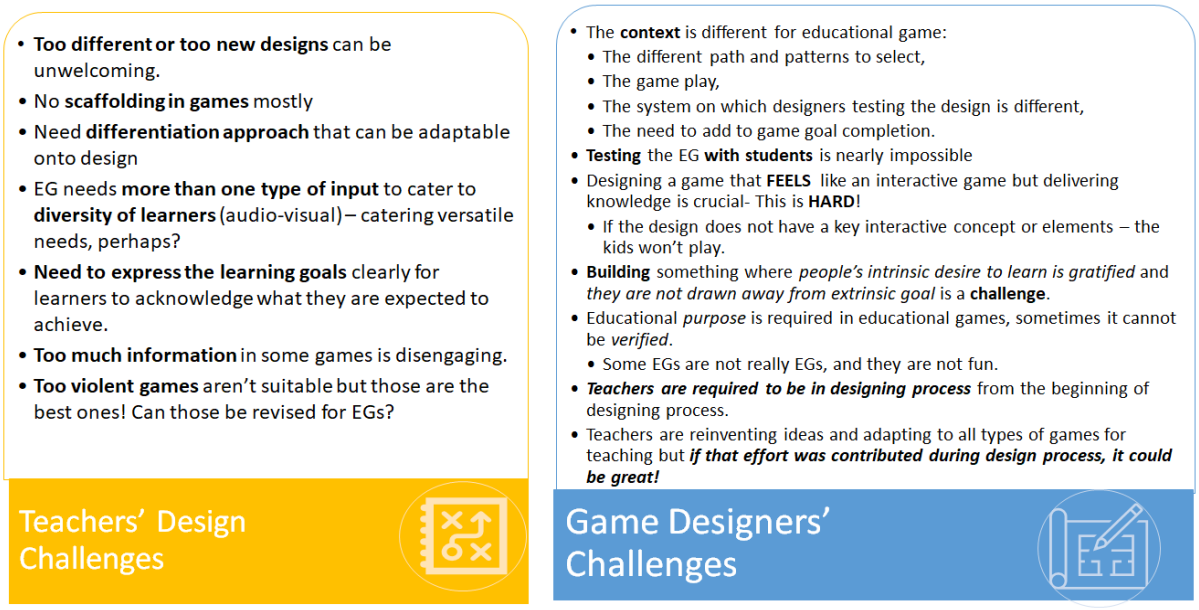

Figure 4: Design Challenges encountered by participants groups

Teachers further advocated the need to enable various learning abilities and develop more inclusive design options. Lastly, teachers advocated the need for adaptable designs to promote differentiation approaches and possibly aid teachers' needs to some extent. The reason for differentiation approaches or strategies potentially indicates the need for diverse, versatile interactive methods within the game design to accommodate instructions that are effective for high-ability students as well as students with mild to severe learning abilities (Weselby, 2022). Conceivably, the content and the learning environment of EGs can be designed in a way that caters to differentiated instructions or provides a variety of ways in which one task or learning outcome can be achieved or learned through the game design.

Design challenges encountered by GDs (Figure 4) complemented teachers' challenges. To begin, GDs addressed their awareness of reinvention and adapting ideas by teachers as they use games in the classroom and advocated the need for collaboration, for instance:

> *[GD_3]: "Teachers are reinventing ideas and adapting to all types of games for teaching, but if that effort was contributed during the designing process of EGs, it could be great!"*

> *[GD_1]: "Teachers use all games, not just educational games! Even Civilization is not really for educational purposes, but now it has reformed because of teachers being involved in later versions of the game sequel! With teachers, we can work wonders!"*

GDs asserted the need of teachers' requirements in the designing process to enable verification of game design (GD_2). Interestingly, GDs emphasized that assessing, testing, or verifying EGs is difficult, time-consuming, and limited in their project timelines. GDs acknowledged that mostly, the reason for EGs failing is because of a lack of teachers' insights into the design process. Lastly, in comparison with teachers' emphasis on differentiation inclusion within game design, GDs asserted this as a design challenge (GD_1).

> [GD_2]: "*teachers are required to be in a designing process from the beginning...because educational purpose is required in EGs, and sometimes it cannot be verified*".

> *[GD_1]: "Teachers use all games, not just educational games! Even Civilization is not really for educational purposes, but now it has reformed because of teachers being involved in later versions of the game sequel! With teachers, we can work wonders!"*

> *[GD_3]:"designing a game that feels like an interactive game but delivers knowledge is crucial but enormously hard!"*

This view reconnects with the environment (*situation*) in which learners play, and how the learning content is designed within the game. These findings suggest that, in general, game designers balance the process of designing games and EGs to some extent; but the factors stated above influence the requirements of each design distinctively. This resonated with the [GD_3] suggestions, below:

> *"Contextualizing how EGs are designed differently from other action-based games. The difference includes aspects like type of paths, patterns of selection, gameplay, system in which we design and test differently from which the players may play on, adding goal completion, or even the way instructions are designed… it is iterative and sophisticated!"*

Some additional points were noteworthy: (1) good games are costly, and schools disagree in implementing such games, (2) teachers' need to consider their students learning abilities as a priority to achieve engagement and understanding versatile levels of learning acquisition with every student. Here, the teacher mentioned their fear that the "*game failed to deliver what she thought was intended when she play-tested it*" [T_1] and versatile learning abilities is highly prioritized. Lastly, teachers wondered whether the game designers/publishers could narrow the age gap for EGs to achieve more focused and reliable expectations within the game levels progression. As teachers suggested:

> *[T_3]: I need to know my students' learning proficiency, and cater to larger learning abilities...*

> *[T_2]: It is always hard to predict their reaction and to watch them adapt to a new game is both great and frightening.*

Lastly, game designers added that it is important for EG to be context-based where "cooperative learning, explorative and discovery learning" can be enabled.

4.2 Prompt Question 2: What Are the Pains and Gains Of …

This question was prompted to participants to learn and understand what experiences the teachers and game designers have had with designing, using games, and collaborating to design EGs. Pains and gains are also sometimes used as 'hopes and fears,' which is described as one of the tools to accomplish such learnings from stakeholders in DT (Crawford, 2018, August 2). The purpose of this question is to give stakeholders the chance to identify and discuss their *pains and gains*. As a facilitator, it is crucial to create an emotionally safe environment for everyone while working to level the expectations and complete the activity. Figures 5 highlight the emerging views with quotes during data analysis.

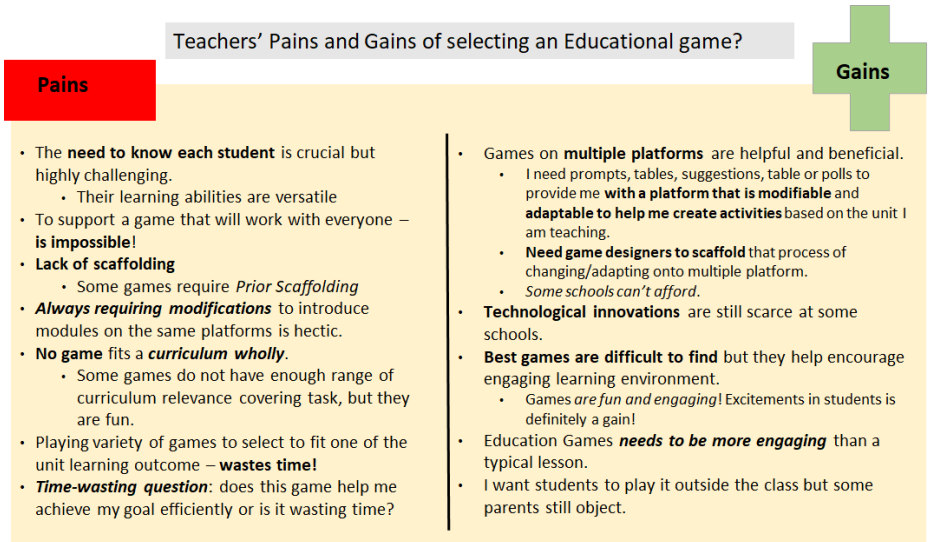

Figure 5: Teachers' quotes on pains and gains of selecting EGs

Figure 5 shows the common views discussed by teachers when the question was prompted: ***What are the pains and gains of selecting an educational game?*** Focusing on seeking their past confrontations of selecting EGs for their classrooms. These responses reveal that the wide range of ICT tools (hardware and software or even internet connection stability) that are available to schools within Australia may not always be sufficient. Teachers have mentioned that as they train other teachers, some tend to resist the change due to old learning strategies. Admittedly, teachers believed that 21st-century skills "*require a change in teaching strategies, but not all teachers find it beneficial* [T_4]".

- **Pains**: the emphasis on the following: knowing students' needs and learning abilities, lack of scaffolding within the game which requires prior knowledge and more time during classroom, games

require modification to accompany curriculum as no game fits curriculum wholly, selecting relevant games wastes time and this adds onto how game can help achieve learning goals efficiently to the students.

- **Gains**: teachers highlighted that: games should be on multiple platforms with modification and adaptability functionalities to add creativity tasks relevant to the curriculum, games need in-built function to scaffold the tasks, scarcity of technological innovations in school hinder tech-savvy students' expectations, and unable to find good games that are engaging and motivating.

Teachers indicated that adaptable games work effectively, save time and easy-to-use games/EGs provide an easy transition between learning activities.. Despite this, currently teachers contend with ICT scarcity in some schools, emphasising that the "*best games are difficult to find [T_5]"* Perhaps this reveals that the game designing industry and education sector are yet to converge to meet the necessities of their stakeholders and users of the system.

GDs' views and quotes shared (Figure 6) when asked: ***What are the pains and gains of designing an educational game?*** GDs revealed some views similar to those of the teachers and some reflective experience in terms of using and designing EGs. They highlighted that their 'fear' about designing EGs is that its neither fun nor educational "*If I'm not able to marry, like make the thing that I'm trying to educate on fun thing maybe it's difficult to construe it into an enjoyable topic?"* [GD_5]

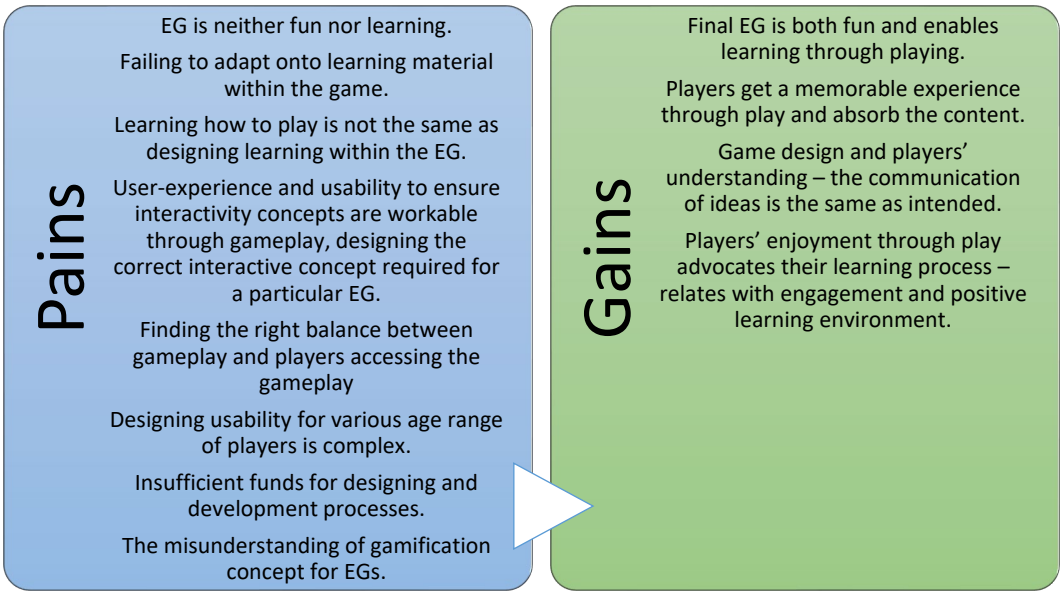

Figure 6: Presents quotes and summarised points from Game designers' participants

With that, some thought-provoking questions were prompted by them about how the balance between learning the topic through play can be achieved, as quote "*can the desired outcome matches the curriculum? [GD_5]*" or "*the learning outcome of the topic? [GD_6]*". This suggests that they would consider such thoughts when a teacher is not present in the designing or requirement gathering process. I argue that every topic has a possibility of being 'fun', although achieving this has been reported as being problematic (Tang and Hanneghan, 2014, Adams, 2010, An and Cao, 2017, Wei and Li, 2010). However, the reasoning was not clarified by the game designers. It can be assumed that due to the lack of collaborative designing with teachers implies that combining a subject-topic with fun element in an EG design is difficult to achieve. GDs added that player's psychology and target players' age can be researched and helps to some extent (see quotes below). Recognizing that this is a crucial requirement needed by game designers, it can be argued that there is a lack of empirical research studies (descriptive and experimental methods) noted previously (Keogh, 2021, Boud et al., 2013, Keogh and Banks, 2018), and it impacts game designers' practice of designing EGs for classroom players to learn their gameplay reactions or interactions with UX and the usability (Nagalingam and Ibrahim, 2015, Hagen, 2011).

[GD_2]: "the design theories related player's psychological/cognitive development allows me to research on the age group selection for design"

[GD_1]:"the design for each age range can make or break the game."

To summarise the *conversation starters* activity results, both game designers and teachers have sparked the responses based on their experiences towards using and designing EGs, and the suggestions, opinions, and views have demonstrated their expertise to generate creative and outside-the-box thinking where the designing and using of EGs is concerned.

5. Concluding Remarks

The *conversation starter* activity raised crucial points that were relevant to the needs and expectations of game designers and primary school teachers. This contextualizes the importance of why their experiences accumulated over time in their practice represent a strong interconnection with the way they *interact* with their audience (students as players and gamers/players). Additionally, it sheds light on what game designers identify as educational, what their challenges and barriers they encounter in designing processes, what are the design challenges, and how their practice as game designers has accumulated reflective knowledge and *growth* in the experience of designing games over time. Lastly, they also added the '*pains and gains*' of designing an EG and contextualized their points based on the demographic and context provided by the facilitator(myself) as primary school children (ages 6-11) and classroom. The summarized and prominent results are presented in the following paragraphs on EGs, and design challenges encountered by both groups of participants.

I observed that teachers' thoughts on *pain and gains (activity)* of selecting an EG appeared to converge on a surface level with the game designers' in designing an EG. Teachers and game designers projected similarities, as shown in the Figure 7 below. Although the similarities may seem like differences, but the teacher's comment on "good games are costly…" is relevant to game designers' comment about "Designing usability is a lengthy process…" which also leads to costly playtesting. Thus, the EGs tend to fall-into 'bad design' categories.

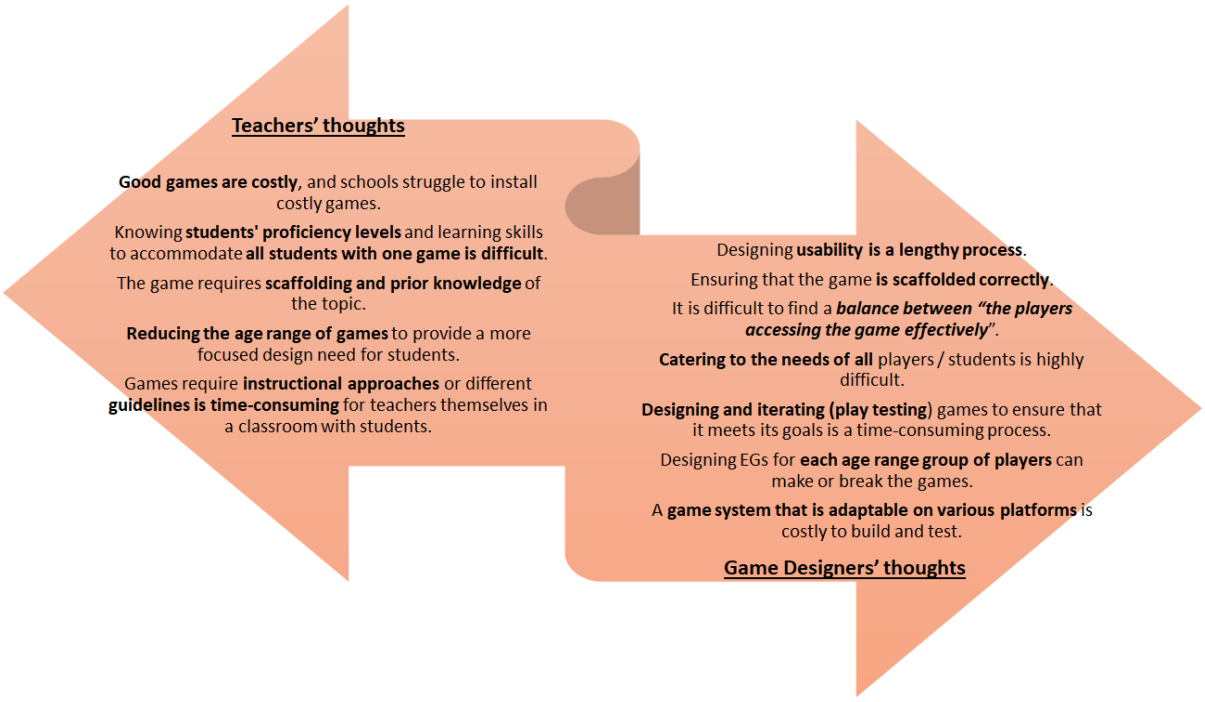

Figure 7: Parallels between both teachers' and game designers' responses about EGs

For further research, I would like the researchers in gaming, educational games design to consider the position of game designers and teachers in the designing process to help communicate, understand, and provide a platform for them where they can collaboratively discuss ideas. The Parallels and the methodology used in this case to help engage participants in designing thinking and creative techniques to ignite the questions that are normally unexpected. Sharing experiences from their practices suggested that there are reasons why teachers find good games costly because game designers go through a lengthy testing process, where EGs generally don't get through a testing process because of lack of funding. I would recommend re-designing questionnaire relevant to the prompts shared in this paper and perhaps apply in testing a game concept or prototype of the games between relevant stakeholders.

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Integrating Reinforcement AI Into the Design of Educational Games

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Abstract: The emergence of reinforcement-based AI for text generation (Chat-GPT) and image creation (Dall-E) has opened a wide range of possibilities for changing the game design and development process. While game development researchers have mostly focused on integrating these technologies to improve production workflow and demonstrate their use in the creation of content for entertainment purposes (intelligent NPCS), there is very little knowledge on how to integrate this technology into the design of educational games. In this paper, we present the results of integrating reinforcement AI (text and image generation) into educational gaming experiences by graduate students enrolled in a game-based learning course. The students were given a core set of requirements that enable the integration into their project with some flexibility on the desired educational outcome. The produced experiences were then evaluated by a small sample of experts (gaming and learning sciences) and their observations were compiled. Specifically, we describe the wide range of experiences developed by the students and the results of a qualitative study with a small group of experts that evaluated these experiences. Our results indicate that reinforcement AI-based integrations into educational game design and development helps enrich the user experience and has the potential to improve learning outcomes.

Keywords: Educational game design, Reinforcement AI, Text completion, Image generation

1. Introduction

Educational games are a large and profitable industry, estimated at about twenty million dollars in 2007 (Susi, Johannesson & Backlund, 2007). Due to the large amount of money at stake, educational game developers are looking to minimize costs and increase profit by making more games at a lower cost. A significant cost in the creation of games is associated with the content. Content can take many forms such as rich narrative text, dialogues and scripts, imagery, environments, props, objects, and animation to highlight a few. Large language models (LLMs) have shown potential in generating video game content, including characters, quests, dialogue, and even entire game narratives. These models use deep learning techniques to analyze and learn from vast amounts of text data and generate new content that is similar in style and tone to the original data.

Reinforcement learning (RL) is a type of artificial intelligence (AI) that involves training an agent to make decisions in an environment by rewarding or punishing it based on its actions. Large language models (LLMs) can be used in reinforcement learning to provide the agent with a natural language interface to the environment it is interacting with. One application of reinforcement learning with LLMs is in natural language understanding and generation. The LLM can be trained to understand natural language input from the user and generate natural language responses, allowing the agent to communicate with humans in a natural and intuitive way. Another application is in game playing, where RL algorithms can learn to play games such as chess, Go, or video games, by interacting with the game environment and receiving rewards or penalties based on their actions. LLMs can be used to provide the agent with additional context or information about the game environment, such as character descriptions or game lore, which can help the agent make more informed decisions.

LLMs can assist in-game content generation by generating NPC dialogue. NPCs, or non-playable characters, are characters in a video game that are controlled by the game's AI rather than the player. These characters often have scripted dialogue that is pre-written by game developers. By training a large language model on existing NPC dialogue, it can learn to generate new dialogue that is consistent with the game's style and tone. Another application is generating quests or storylines for the game. By training a language model on a large corpus of fantasy or sci-fi literature, for example, it can learn to generate new stories and quests that fit within the game's world and narrative. This approach can help game developers create more content in less time and generate new and creative ideas for quests and storylines.

Finally, LLMs can be used to generate game characters, including their backstories, personalities, and motivations. By training on a large corpus of character descriptions from literature or other media, the model can generate new and unique character concepts that can be used in a game. Overall, large language models have the potential to be a powerful tool for video game content generation, providing game developers with new and creative content ideas and reducing the time and cost associated with creating game content from scratch.

These needs leave us with three research questions:

RQ1. To what extent can RL assist in the educational game design process?

RQ2. What is the role of the content creator or producer when using RL during content creation?

This paper aims to provide answers to these two research questions. First, this paper discusses current research in both RL and LLMs and their application in game development. This is explored further by having students integrate OpenAI and the Unity game engine to build representative educational game prototypes. These prototypes are then evaluated by experts and a survey on the efficacy of using auto-generated game content is administered to get some insights into the research questions.

2. Current State of the Art

Procedural content generation (PCG) has been an emerging area in game development and particularly the appeal lies in its use of algorithms to create game content such as NPC dialogue, levels for puzzles, and sometimes entire worlds without human intervention (Liu et al., 2021). PCG provides dynamism and unpredictability to the game experience as players are not completely sure what the nature of the content and level progression can be. PCG has been applied to the game design process in several ways and the most common approaches have been 1) Randomization – where the content is generated randomly with a loose description of the parameters; 2) Rule-driven – where the content is generated by a defined set of rules and provides more structured content; 3) Evolutionary – where the content is generated based on what the player does in the game and provides greater dynamism and richness to the experience. Some of the common examples of PCG use in popular games include Minecraft, Rogue Legacy, Spelunky, and No Man's Sky where PCG has been typically used to generate the worlds and levels in the game.

LLMs have the potential to expand the use of PCG for game content that is based on narration and dialogue for use within the educational game context. Training an LLM on existing educational content and using the trained model to produce rich and real-time text generation for educational games has been achieved in the context of building dynamic quizzes and tests. The trained models also have demonstrated the ability to adapt to the learner by adjusting and changing the nature of the content to suit their needs. Todd et al. (2023) recently show the use of GPT-3 for generating a level for a puzzle game *Sokoban* and conduct a study where participants cannot distinguish between human and AI-generated content. Ashby et al. (2023) introduce the idea of generating quest-based dialogue within an RPG game using an LLM approach. They evaluate and demonstrate that the quests and the resulting dialogue match the performance of human-crafted quests in terms of fluency, coherence, and creativity. Story and narrative generation are also demonstrated via the Wordcraft tool which assists users in writing stories and provides better assistance in producing creative and novel narratives compared with not using the tool (Yuan et al., 2022). To further illustrate the growing interest in the area of applying LLMs for game content generation, the 2023 IEEE Conference on Games ran the first ChatGPT4CG competition where teams had to develop AI that creates character-like levels for the game *Science Birds* (Taveekitworachai et al., 2023). The competition was evaluated on stability and similarity to human-crafted characters.

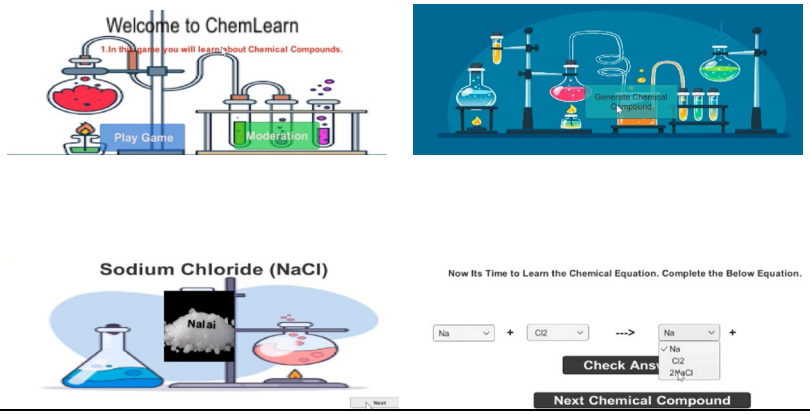
The majority of the experiments that study the integration of LLMs with game content creation use OpenAI with the Unity game engine. OpenAI provides access to a variety of AI models, including GPT-3, which can be used to generate text, translate languages, write different kinds of creative content, and answer questions in an informative way. When used together, OpenAI and Unity can be used to create games that are engaging, interactive, and intelligent. For example, OpenAI's GPT-3 can be used to generate text-based content for games, such as dialogue, descriptions, and even entire stories. Unity can then be used to create the visual elements of the game, such as the characters, environments, and gameplay. In *Ava: Children of the Machine* GPT-3 is used to generate text-based content, such as dialogue and descriptions. In *The Bard's Tale IV: Barrows Deep* GPT-3 is used to create AI characters that are more intelligent and realistic and in *Project Wingman* GPT-3 is used to create chatbots that players can interact with. While relatively a new field, GPT-3 and Unity have also been combined to develop educational game content in language learning (Zografos and Moussiades, 2023). With demonstrated success in creating human-like content for game development, there is indeed great enthusiasm in the development community for continuing to improve the integration of tools such as OpenAI and Unity which will lead to newer research and development efforts in studying the role of LLMs for developing rich, engaging, and meaningful content for educational games. In the next section, we present our experiment that starts the process of thinking about the integration of OpenAI and Unity and demonstrates their capabilities by developing simple educational game prototypes.

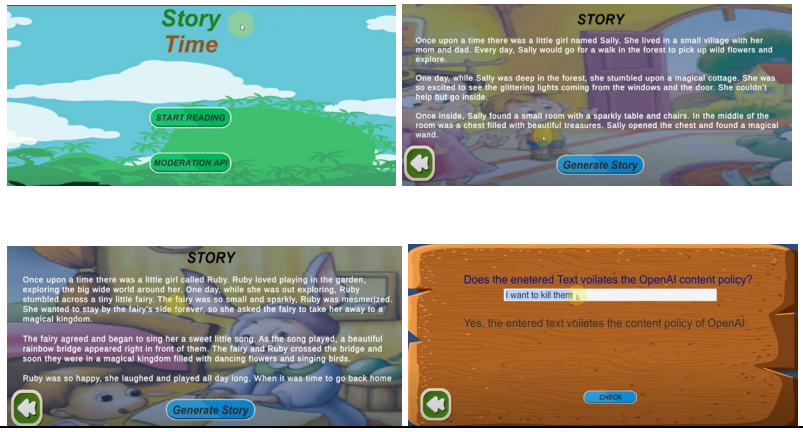
3. Experimental Design

For this study, 10 computer science graduate students enrolled in a game-based learning course were provided a project to complete as part of their course activities. They were provided an OpenAI API Unity asset and asked to create a new Unity 3D component based on this asset. Once the component was created, they could add this to any game object in their game and use GPT-3 for text-based information generation and DALL-E for an image-based generation. The steps that were necessary to complete the project include: 1) Setup – where they would install the provided asset, create an OpenAI account with a provided organization ID, create an API key, and verify the credentials via the Unity editor. Once setup is complete Unity and OpenAI can communicate and the requests from the game via the OpenAI API would get validated; 2) Review existing components – the downloaded asset comes with two example components *OpenAiImageReplace* and *OpenAiTextReplace* that can be added to any Unity game object in the scene and tested to check if text and image generation are working; 3) Review existing code – students are asked to review the provided code samples for the two components and also review the OpenAI API documentation and learn how the integration with Unity works; and lastly 4) Create something new – students were asked to create a new component that has an educational objective such as using the text generation to create narrative pieces or the image generation to create new game textures or the combination of the two. Some initial ideas that were proposed include the creation of a children's storybook, building a dialogue system that helps practice math problems, and creating an interactive and dynamic quiz on a particular chosen topic. Students were asked to challenge the limits and be creative.

Students had three weeks to complete the above steps and demonstrate their work. Table 1 lists some sample projects that were created by the students. The paper presents some of these projects as there was considerable similarity in the chosen ideas for the project among the students.

Table 1: Sample projects produced during the course

Objectives and goals	Screenshots
Teach chemical compounds – GPT-3 generates the compounds and the element composition on the fly; DALL-E generates the compound image. Students are given AI-generated compounds, with representative images and they must create the correct bonding equation to progress in the game.	
A *Jeopardy-style* game where the player selects a topic, and the questions and answers are generated by OpenAI. Topics include history, science, and social studies. Additionally, has a Chatbot where you can ask questions or get help with math.	

Objectives and goals	Screenshots
A storybook game for children where the content is generated by OpenAI including the text and images. Includes a moderation API so that explicit or poor content can be filtered before displaying it to children. The game generates new stories and images while moderating the content each time the player clicks the button.	

The course had a final team project that tasked the students to learn the concepts and create an educational game prototype. Among the three project teams, one team chose to integrate OpenAI with their final project game titled *Traffic Learner*. The game was aimed at those learning to drive a vehicle and familiarizing themselves with traffic rules and regulations. The game had three major components: 1) Information – learn and familiarize with traffic rules and regulations, the content and imagery were generated via OpenAI; 2) Quiz – test the knowledge of the rules and regulations, the questions and answers were generated by OpenAI; and 3) Play – practice driving in a real-world setting by following the rules and regulations. Figure 1 shows the three modes developed for the game.

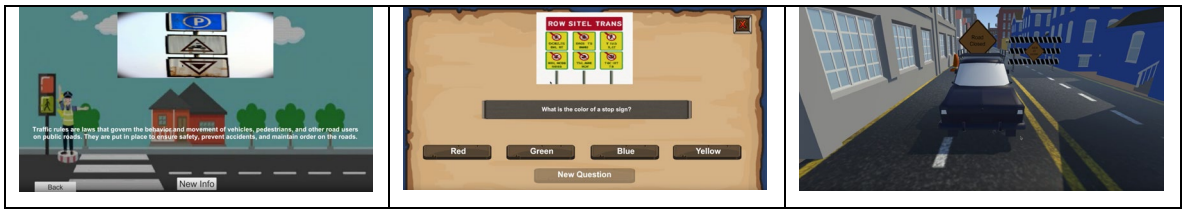


Figure 1: Information (left), Quiz (middle), and Play (right) areas of the Traffic Learner game

4. Findings

Two faculty members evaluated the effectiveness of integrating OpenAI and Unity in the student projects. One faculty member was an expert in human-computer interaction (HCI) and the second faculty member was an expert in software engineering (SE). This helped the evaluation be conducted from multiple viewpoints and lenses. The feedback was gathered via a data questionnaire that the members filled out during student project presentations. The HCI faculty member raised questions about the trust in the content and the possibility of misguiding the player. The SE faculty member raised questions about the content's replicability and consistency. They were also unsure about issues relating to copyright and ownership, especially with the auto-generated imagery. Overall, both faculty members were supportive of exploring ways to integrate OpenAI with Unity and building educational game experiences. This provides a positive direction for our first research question on the role of OpenAI in assisting with educational game design.

OpenAI and Unity integration also had many challenges that would need to be overcome in the future. Time inconsistency was the most common challenge, this relates to the time it takes OpenAI to generate the content. The factors that influence this include the load on OpenAi's servers, the nature of the content desired, and the bandwidth availability during play. Potentially, players may have to wait for seconds at large to have OpenAI content be produced and displayed while playing the game. Some suggestions include pre-querying methods for generating and storing the content and making it available via a just-in-time approach. This requires prior knowledge of what the game's content needs are and may not always work when the environment is rapidly evolving. For example, if a player needs to talk to an NPC and the content produced for the dialogue depends on what the player asks then a just-in-time approach may not work. However, if the question set is limited and well-known prior to the query then the possible answers could be populated in advance. There is limited understanding of our second research question on the role of humans in developing

a game that uses OpenAI-generated content. While we cannot completely rely on OpenAI content in all situations, there are positive use cases where a collaboration between a human and AI is necessary for generating desirable educational game content. Further research in this area is necessary to explore the right circumstances and situations for tight collaboration. It is also foreseeable that advancements in the text and image generation methods within OpenAI and other LLM research projects could provide the framework for generating and integrating content without any human intervention.

5. Future Work

There is real potential for the integration of AI-generated content in educational games. When the objective is to build proficiency in a particular topic and speed of development becomes necessary, then such an integration can be valuable for educational game designers and developers. In our prior work, we demonstrated an approach to being content-agnostic when rapidly designing educational games via the content-agnostic game engineering (CAGE) framework (Baron et al., 2016). AI-generated content can play an important role in how CAGE (Verma et al., 2021) can be further developed to add greater agility and speed in development. Stealth assessment techniques (Verma et al., 2019) can further be enhanced and response mechanisms that manage the dynamism in the content can be efficiently handled. Figure 2 shows the future modification to the CAGE framework and would form the basis for future game studies in closing the loop between AI-generated content, agnostic content, and stealth assessment. This would allow for the game to decide in real time whether to pull in static inactive content and make that active or reach out to OpenAI and ask for AI-generated content. The nature of the AI-generated content could additionally be tied with the mechanics component and based on the game mechanic (narration, puzzle, level, etc.) appropriate queries could be handled by OpenAI. The stealth assessment aspects of the framework (in yellow) would be able to provide an additional layer of information back to the system on whether the content generated by the AI would need to be changed or updated leading to a cyclical evolutionary approach to the game.

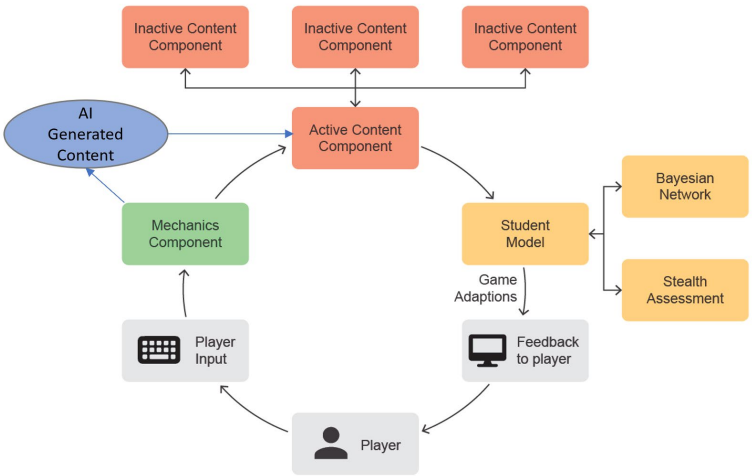


Figure 2: The modification (in Blue) to the CAGE framework

6. Conclusion

In this paper, we introduced the integration of reinforcement learning AI techniques that apply large language models within the context of educational game design and development. We compiled and presented the products developed by students and student teams when tasked with integrating OpenAI and the Unity game engine within the context of a graduate-level game-based learning course. Our findings provide early insights into the ability of reinforcement learning techniques in assisting the process of educational game development and the role that human content creators would play when employing such techniques. There are several limitations with advancing the use of AI-generated content within educational games. Quality control of the generated content can be limiting, for example the content that is rule based can such as chemical compounds can be reliably presented with the possibility of adding additional constraints such as safety of the resulting mixture. Another possible concern is being able to closely match the generated text and images so that the resulting experience does not appear to be ambiguous to the player. As research in LLM matures and

connectivity across openAI tools increases, the potential for risks associated with trust, validity and ambiguity of the generated content have the potential to reduce.

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The Need for Game-Based Learning Methods to Address Cyber Threats

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Abstract: Cyber security threats are increasingly a serious concern to organisations, with an annual worldwide cost of a trillion dollars in 2021. Potentially the most significant contributor to cyber security threats is the human element, yet this has typically been insufficiently addressed in proposed solutions. Significant resources have been allocated to software, training and other solutions designed to tackle this threat, yet existing methods to improve cyber security have failed to deliver the desired results. Commonly cited issues include the lack of engagement in training, leading to disinterest and a 'one size fits all' approach, meaning some groups benefit from training more than others. This study will examine the need for game-based training methods in addressing cyber security threats caused by human error. Game-based training methods have previously been proposed to improve engagement in training and this study will discuss other potential benefits of game-based training. The aim of this work is to justify the use of game-based training methods in cyber security and begin to determine which aspects of games may be most effective at causing long-term positive behaviour change. Following an extensive literature review, a pilot study was run in which a survey was presented to 37 individuals who have taken cyber security training in the past, to query opinions and perceptions regarding cyber security training participants had previously taken, and how they feel they would behave when faced with certain cyber security threats. Upon analysis in SPSS, the results of this work indicate that factors such as training frequency and exposure to cyber security attacks have a significant impact on cyber security behaviour. A correlation between engaging training and impact of training on behaviour also serves to justify the development of such training methods. When combined with previous results on cyber security training this highlights the need for training to be engaging, regular, and relevant, and shows that the realistic simulation of cyber security threats (such as in game-based training) is of significant benefit. These results will help inform future development of effective game-based training methods and encourage their use more widely.

Keywords: Game-based learning, Workplace, Non-Expert, Cyber behaviour

1. Introduction

Online digital systems have become a fundamental component of society today. A significant proportion of the population has some form of online presence (Johnson, 2021) with many individuals doing their shopping, banking, and socialising online. This is not limited to individuals, as Abawajy (2014) notes that many organisations are becoming increasingly dependent on such digital technologies. While these systems offer convenience and efficiency, they are not without downsides. A report from PwC (2013) along with a recent report from Accenture (2021) show a consistent increase in the average number of cyber breaches faced by organisations each year.

It has been suggested that humans and human error is the weakest link in the cyber security chain (Zwilling *et al*., 2022; Cain, Edwards & Still, 2018). Streeter (2013) suggested that over 35% of breaches are due to human error, with a more recent Kaspersky (2017) analysis finding at least 27% of breaches due to careless employees, loss of hardware, or social engineering.

Lack of engagement is a significant issue reported with existing security training programs (Furnell, Bryant & Phippen, 2007; Reeves, Calic & Delfabbro, 2021). Haney & Lutters (2018) describe a perception of cyber security as boring and dull to many individuals, discouraging engagement. It would, therefore, be beneficial to increase the engagement of security training programs. Games – particularly video games – are well known for being engaging (Laffan *et al*., 2016). There is evidence that game-based learning is effective at causing behaviour change (Hamari, 2016), which existing cyber security training has been, however game-based cyber security training is not yet widespread.

This study will aim to work towards a method of cyber security training which addresses lack of engagement, through the use of game-based methods.

2. Literature Review

2.1 The Effectiveness of Current Cyber Security Training

It has been frequently stated that existing cyber security awareness methods are insufficient (Bada, Sasse & Nurse, 2019). The distribution of both paper-based and electronic resources can be considered among the most basic form of training. While it is possible for conventional delivery methods to reach a wide range of individuals, the actual impact is difficult to measure. Kumaraguru *et al.* (2007) look at responses to such delivery methods, finding security notices ineffective at improving perceived awareness. Similarly, Bada, Sasse & Nurse (2019) describes the materials themselves as often not being engaging, which can lead to the training being unsuccessful, potentially due to trainees getting bored and losing focus (Reeves, Calic & Delfabbro, 2021).

Instructor-led training methods are commonly used and involve the use of an expert to deliver the relevant information from the top down are also common. Haney & Lutters (2018) discuss the variance in delivery by instructors, noting that audiences can be lost by poor presentations, even when the information and material are valuable. Despite being generally more effective than conventional delivery methods in improving cyber security behaviour, they are more resource-intensive to implement, and still rely on the ability of the instructor.

Individuals not engaging with cyber security training has been identified as a significant issue with existing cyber security training methods (Reeves, Calic & Delfabbro, 2021; Bada, Sasse & Nurse 2019). As a result, existing cyber security training methods have generally been found to have been ineffective, at least in part leading to an increase in the security incidents.

2.2 Games for Cyber Security Training

Games, and in particular video games, are known for being engaging activities. Hamari *et al*. (2016) find a positive correlation between the challenge within game-based learning and the engagement of participants, which further correlates to perceived learning.

Game based training is a proposed alternative to more traditional forms of cyber security awareness training (conventional, instructor-led and others). A notable advantage of game-based cyber security training is the engagement factor of video games, which can also contribute to increased motivation (Zhang-Kennedy & Chiasson, 2022).

The concept of *flow* is very important in the study of engagement. Flow refers to a state of intense focus to the point of loss of awareness, brought about by a balance between challenge of an activity and skill level (Nakamura & Csikszentmihalyi, 2002). Kiili (2005) suggests that flow has a positive impact on learning, indicating that a training method involving flow would help increase engagement with training materials, which has previously been cited (Reeves, Calic & Delfabbro, 2021) as being beneficial to learning. Challenge is a significant factor in the induction of flow, as Jin (2012) determines that challenge contributes towards flow, but only when the challenge is matched to skill level. Sherry (2004) goes on to describe a gradual but continuous increase in difficulty as most effective in inducing flow. The impact of the difficulty of training will therefore be a worthwhile inclusion in training studies.

Game-based methods do not necessarily solve all issues facing cyber security training but where appropriately challenging and engaging, game-based training methods can take advantage of flow to improve the positive impact of cyber security training programs.

2.3 Effectiveness of Existing Game-Based Training Methods

Some game-based cyber security training has been developed and investigated previously. Zhang-Kennedy & Chiasson (2022) and Hendrix, Al-Sherbaz & Bloom (2016) reviewed multiple game-based tools for cyber security training finding that only a small proportion of investigated tools (fewer than one-third) had been properly evaluated, and even fewer in their long-term impact. Where they have been evaluated, outcomes were typically positive – demonstrating some positive impact on cyber security awareness/behaviour, at least immediately following the training. Only six of the reviewed games directly matched the demographic of this study, but these studies found generally positive results as well.

One of the most well-known tools reviewed is Anti-Phishing Phil (Sheng, S. *et al.*, 2007), a game in which players (aimed at non-expert players) must distinguish between real and fake URLs, represented by worms. Despite this game being referred to often, and several studies into its effectiveness, there is no investigation of how this game impacts knowledge and behaviour of participants over a period longer than two weeks.

The long-term impact of game-based methods has not often been investigated, and even in studies such as Egelman *et al.* (2016) in which a long-term impact is assessed, the population studied is limited (in this case to university undergraduates). A part of determining whether game-based methods are useful in awareness and behaviour modification is the assessment of cyber security awareness/behaviour. To achieve this, a long-term assessment of behaviour change would be very useful.

3. Methodology

The research this study aims to work towards involves taking advantage of the challenge and engagement of game-based methods in order to change the behaviour of adult users with limited digital knowledge (non-expert). To approach this problem, this study aims to discover what behaviours end users currently have, and how they are impacted by cyber security training they have taken in the past.

Part of the survey also aims to investigate how users perceive cyber security training, to determine which aspects are most in need of improvement and whether game-based training would likely be effective. The target group of this study is adults in the age range 24-64 with limited knowledge of cyber security, who have taken part in some form of cyber security training. N = 37 participants responded to requests for participants, which were shared in university and affiliated groups. All participants who responded before the deadline were included in the data analysis. N = 36 participants were within the desired age range of 24-64 and were mostly known to have taken part in similar cyber security training programs (At least N = 35 participants have taken part in training, at least N = 31 through their job).

3.1 Survey Design

This survey contains 18 questions, some of which were adapted from a previous study – GICAST (n.d.), but were mostly written specifically for this study. The questions aim to primarily assess the users' perceptions of cyber security training - both their perceptions of the effectiveness of training, and how they perceive their experiences of it. The questions analysed use a Likert scale, typically from 1 to 5 (strongly disagree to strongly agree).

The first set of questions aims to address the current cyber security behaviour of end users, as current cyber security behaviour is considered to be insufficient to combat the growing impact of cyber threats (Zwilling *et al*., 2022; Cain, Edwards & Still, 2018). The questions focus on actions participants may or may not take, that are typically considered either good or bad practice. This will overlap with how users believe they should behave in cyber contexts, as participants may not be aware of how they can best protect themselves.

Most of the remaining questions focus on attitudes towards existing cyber security training. Works such as Bada, Sasse & Nurse (2019) suggest that current cyber security training has failed to cause the desired level of behavioural change, and one of the aims of this survey is to discover whether participants feel that their behaviour has been changed by cyber security training, and if so, why they feel this is the case.

Once developed the survey was internally distributed via an online link. The responses were collected over 12 weeks, and then analysed quantitively and qualitatively.

3.2 Interview Design

Five participants then took part in focused interviews, with 15-20 more detailed questions based on their survey responses, such as how they feel cyber security training has impacted their day-to-day lives.

These interviews aim to improve the detail of information gathered throughout the initial surveys and allow questions that have not been addressed through the surveys to be asked.

Data from these interviews is used to contextualise results from the surveys and offer some additional insights.

4. Results and Analysis

In total, the end user survey had N = 37 responses before the response deadline. Of these N = 23 were aged 24-44, N = 1 aged under 24 and N = 13 aged 45-64. N = 14 were female, N = 1 non-binary, N = 21 male and N = 1 declined to say. From these results, several measures were constructed. All analysis, unless stated otherwise was carried out in SPSS version 28, using similar methods to that of Hong & Furnell (2021) in which the impact of various factors on behaviour were analysed.

First, relevant factors were isolated (such as engagement), then correlations will be run between each of these (where appropriate) and significant correlations were recorded. Finally, a linear regression was run on the most important dependent variables, iteratively eliminating independent variables to find the strongest model.

A behaviour score was calculated for each participant, based on their responses to each of the Likert-style questions which refer to their cyber security behaviour (such as whether they use anti-virus software, or use strong passwords) and whether they have changed their behaviour in response to cyber security incidents (such as whether they are more cautious, or sought additional training). Each of these answers were normalised (to have a score between 0 and 1), reversed if necessary (where the question indicated a negative behaviour), ignored if no response was given and then averaged across all included responses with equal weighting. A total of 16 variables were used in this calculation. The final behaviour score for each participant is a number between 0 and 1, the lowest of which was 0.51667, and the highest was 1.

4.1 What is the Current Cyber Security Behaviour of end Users?

Past work has claimed that cyber security behaviour among the general population is poor (Kaspersky, 2017). Using the cyber security behaviour metric, the mean cyber security behaviour score returned was 0.79, which roughly corresponds to participants *usually* taking the more secure action in their day-to-day lives when faced with cyber security situations, and *usually* responding in a secure way to incidents.

The most significant independent variables that are being measured come from the following questions:

16. How would you describe your current cyber security awareness training?

- Instructor-led in person
- Instructor-led remotely/online
- E-learning (online/ self-directed)
- Simulation-based with videos and case studies
- Game-based training
- Other
- N/A

Figure 1: Question 16 – the basis for 3 of the independent variables tested against the likelihood of participants feeling their behaviour had changed (game-based and instructor-led in person were not selected by any participants)

17. What do you think about the following statements regarding cyber security awareness training that you have taken?

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	N/A
Improved your understanding and awareness about cyber security	○	○	○	○	○	○
Engaging (as opposed to difficult to concentrate)	○	○	○	○	○	○
Relevant (to what you do)	○	○	○	○	○	○
Enjoyable	○	○	○	○	○	○
Difficult	○	○	○	○	○	○

Figure 2: Question 17 – the Basis for 5 of the independent variables tested against both dependent variables

- Training Frequency is an estimate of how often participants are required to take part in training. (Q15)

- Cyber_Attack_Exposure is the number of types of cyber security threat participants report having encountered. (Q8)
- Personal_Responsibility_Level is the number of external entities participants felt were responsible for their online security. (Q10)
- Gameplay_Frequency is an estimate of how often participants reported playing games. (Q6)

Table 1: Correlation between training factors and cyber security behaviour

Predictor	Correlation	Lower C.I	Upper C.I
Training_Frequency	0.400	0.082	0.644
Relevance	0.508	0.199	0.725
Enjoyment	0.303	-0.045	0.585
Engagement	0.196	-0.158	0.505
Cyber_Attack_Exposure	0.420	0.111	0.655

There was significant positive correlation between all considered factors and the behaviour score of participants (Training frequency, enjoyment, engagement, relevance, and previous exposure to cyber threats) as shown in the table above. For enjoyment and engagement, the confidence interval including zero would typically result in any hypothesis being rejected ($p > 0.05$). Nevertheless, given the nature of this study, it is not necessary to discount these results entirely.

Table 2: Partial results of linear regression on cyber security behaviour

Variable	Initial Model		Strongest Model		Final Model	
	Standardised B	*p*	*Standardised B*	*p*	*Standardised B*	*P*
Training_Frequency	0.261	0.201	0.253	0.116	0.232	0.124
Improved Understanding and awareness about cyber security	0.162	0.507	0.198	0.335	-	-
Engaging	-0.434	0.189	-0.465	0.099	-	-
Relevant	0.430	0.051	0.435	0.029	0.431	0.006
Enjoyable	0.250	0.486	0.251	0.341	-	-
Difficult	0.025	0.910	-	-	-	-
Cyber_Attack_Exposure	0.250	0.179	0.303	0.052	0.282	0.065
Personal_Responsibility_Level	-0.042	0.833	-	-	-	-
Gameplay_Frequency	0.069	0.696	-	-	-	-
R^2		0.480		0.475		0.410
R^2 (adjusted for number of variables)		0.268		0.354		0.349

A linear regression was run to find the most significant predictors of cyber security behaviour. The least significant factor was iteratively removed, and the regression rerun, until adjusted R^2 was maximised. In this case, this occurred with two variables having very high p values ($p > 0.3$), so these were removed as unreliable (and this made almost no change to the adjusted R^2 score). The model is still included in the results. The factors of Frequency, Relevance, and Previous exposure to cyber threats made up the final prediction, with the adjusted R^2 value being almost maximised with only these three (the R^2 value could be slightly increased but only with the addition of statistically insignificant variables).

The conclusion that would be drawn from this model is that the relevance of training, the frequency of training and the cyber threats previously exposed to have the greatest (positive) impact on cyber security behaviour.

4.2 What Perceptions of Cyber Security Training Do End Users Have?

It has been frequently stated that existing cyber security training is not engaging and not fun, and these results tend to support that – when participants were asked whether they felt training they had taken was engaging/enjoyable, the mean of the responses were around 3 (3.33 and 2.94 respectively) – which approximately corresponds to a neutral response. As is the case for all the results, the small sample size means it is difficult to make definitive conclusions.

There was a moderately strong correlation between all queried factors and the likelihood that participants felt that training had changed their behaviour. In particular, the correlation between relevance and engagement was particularly strong (around 0.6). It was expected that there would be some correlation between the likelihood of participants feeling that their behaviour had been changed and the types of training they took, however the correlations found were not significant.

Table 3: Correlation between training factors and feeling that training has changed their behaviour

Predictor	Correlation	Lower C.I	Upper C.I
Difficulty	0.345	-0.005	0.619
Relevance	0.599	0.321	0.781
Enjoyment	0.528	0.225	0.737
Engagement	0.614	0.343	0.791

With a more in-depth analysis, there are some moderately strong correlations. Looking particularly at the question "What do you think about the following statements regarding cyber security awareness training that you have taken?" the table above shows various correlations between various responses and the likelihood of participants feeling that previous training has changed their behaviour.

Another linear regression was run on this data, with the dependent variable being whether participants felt that training they had previously taken has changed their behaviour. The method for this linear regression is the same as the regression in the previous section.

Table 4: Partial results of linear regression on whether participants feel training has changed their behaviour

Variable	Initial Model		Final Model	
	Standardised B	*p*	*Standardised B*	*P*
Engaging	0.223	0.393	0.390	0.016
Relevant	0.327	0.053	0.349	0.029
Enjoyable	0.123	0.644	-	-
Difficult	0.366	0.022	0.281	0.040
Instructor-led remotely/online	0.116	0.496	-	-
E-learning (online/self-directed)	-0.039	0.846	-	-
Simulation-Based	0.116	0.496	-	-
R^2	0.565		0.529	
R^2 (adjusted for number of variables)	0.438		0.479	

The (adjusted) R^2 value of 0.479 is higher than in the previous regression, but considering the difficulty of measuring human behaviour, it is difficult to tell if this is a good result. Given results that have been found previously it seems reasonable that engagement, relevance, and difficulty would have an impact on behaviour change.

Ultimately the final model contained only engagement, relevance, and difficulty as the most significant predictors of how likely users feel their behaviour has been changed. All three have a $p<0.05$, which indicates statistical significance. Engagement and enjoyment continue to be influential factors, which are also viewed to

be lacking in existing training. While Enjoyment was not in either model, there was correlation between both variables, and it was excluded by a small margin.

It is not clear whether difficulty of training positively or negatively contributes to actual behaviour change. As these results are centred around perceived change, it may be the case that participants internally correlate the difficulty of training with the effectiveness of training – as they feel that training that is difficult must be effective, while training that is easy may not have much of an impact.

4.3 How do end Users Believe They Should act in a Cyber Security Context?

All participants responded that they believed that they were responsible for their own security. In addition to this, however, 32 respondents of the 37 (86%) felt that at least one of ISPs (Internet Service Providers), employers, technology and government were also responsible for keeping their online information secure.

Additionally, participants felt most compelled to act securely where their behaviour could potentially impact their family members and personal finances (both 35/37). Behaviour impacting peers/strangers was not as compelling a motive (20/35 – still 57%).

4.4 What do end Users Think of Game-Based Cyber Security Training Methods?

Only a single question asked participants what they thought of game-based training methods. There was a mean response of 4 roughly corresponding to a positive response, but not overwhelmingly so. There are many reasons as to why some individuals may be sceptical of game-based training, but it is promising that only 3 of the 35 responses (under 10%) were strictly negative while 25 (over 70%) were positive. As was the case previously, this data is not statistically significant due to the small sample size.

In the interviews, participants were mostly receptive to the use of game-based training options, however, it was frequently stressed that traditional cyber security training methods should not be abandoned and should be offered as an alternative for individuals who do not want to use the game-based methods. Most participants have not taken part in game-based cyber security training previously.

5. Discussion

While these results are interesting, the number of responses is such that it is difficult to make any conclusive arguments. The response pool was limited mostly to university students and researchers, particularly in the cyber security field, and is therefore not directly applicable to the population at large. Despite this, these results can give a good foundation to build upon and are worthwhile to analyse.

5.1 What is the current Cyber Security Behaviour of end Users?

While the overall behaviour score was reasonably high, detailed analysis demonstrates that some further steps should be taken, especially in certain areas in which poor behaviour is commonplace.

There was a clear correlation between the frequency and relevance of training, and the cyber security behaviour of participants. It makes sense that the relevance of training has a positive impact on cyber security behaviour, as irrelevant training would likely have limited impact on behaviour. The frequency of training would have multiple benefits to behaviour – most notably improving retention of material, as well as reminding individuals to behave securely. No training at all, or a single training course at the beginning of employment tend to result in significantly worse behaviour. Adaptive training in response to incidents and new recommendations would likely be an improvement, but there was not enough data to conclude so. The long-term impact of training in cyber security, particularly game-based training, is not well researched, so it is useful to have some empirical data to justify cyber security training being regular.

Previous exposure to cyber threats was another factor that correlated with behaviour. It would seem reasonable that individuals who have previously experienced cyber threats would be motivated to prevent recurrence, but this is not something organisations can control. Having real-world consequences/punishments for cyber breaches has been described by Maalem Lahcen *et al.* (2020) as counterproductive, and so it would be better to simulate these punishments in a safe environment. Reward/punishment mechanics in a simulated game environment could be a solution to allow this, and can also improve flow (Laffan *et al.*, 2016). This would indicate that game-based training is very suitable to the requirements of cyber security training, as it results in greater concentration and learning (Kiili, 2005), while also allowing a natural improvement in behaviour through the simulated exposure to cyber attacks. In addition to this, (more) frequent training would have a significantly reduced cost if training was at least partially automated through a game/suite of games.

5.2 What Perceptions of Cyber Security Training do end Users Have?

There was no indication that participants considered existing training to be engaging or enjoyable consistent with observations such as by Haney & Lutters (2018). In the interviews, participants who had taken limited cyber security training could remember very little of the training they had done in the past, but still felt as though they had learnt at least something from it. The most memorable parts of the training were generally the most fun/interesting parts, though this was not always the case.

Overall, participants felt only somewhat (3.66) that previous cyber security training had changed their behaviour. Participants who found training to be fun and engaging almost always felt that training had changed their behaviour. This perception may not carry over to reality, but similar studies also often use self-report data, so this observation would be using comparable data. It would be useful to know why participants felt that their behaviour changed, perhaps as part of future study.

Participants typically do not feel that cyber security training was enjoyable or engaging, yet participants who found training enjoyable and engaging were more likely to say that their behaviour had improved because of the training, and overall seemed to have better cyber security behaviour.

The relevance of training was another important factor in the perception of training; however, it is possible that this result is largely caused by the positive response to training being relevant, with 26/33 responses finding training to be relevant. Since this was also a positive factor for behaviour, it can be considered important, and is perhaps evidence that training should be more tailored to individuals/groups and not 'one-size-fits-all' – something echoed in Bada, Sasse & Nurse (2019) which reported similar conclusions.

Difficulty did arise as an influential factor in perceptions of training impact, with a moderate correlation. This may be a result of the experience of flow, as the appropriate difficulty of an activity is a significant factor in flow (Jin, 2012), which subsequently positively impacts learning (Reeves, Calic & Delfabbro, 2021)

5.3 How do end Users Believe They Should act in a Cyber Security Context?

Participants typically recognise that they are responsible for their own cyber security behaviour. While discussions with some participants revealed that behaviour is somewhat changed by relying on others, the answers mostly reflect situations beyond a users' control – such as data stored by websites being covered by online safety laws. Good security behaviour in some cases may require some trust in external factors – for example the safety of a password manager. It would not be surprising if in some cases cyber security behaviour was relaxed due to trusting a system that insufficiently protects their information.

Participants were typically more motivated to change their behaviour to protect family members and their own finances than to protect strangers/peers. This makes sense, as finances and family members will usually have a more significant impact on their lives than colleagues and strangers. This may indicate that emphasising the impact of their behaviour on the organisation they work at would be less effective. Instead, it may be more influential to make individuals aware of personal consequences – potential loss of employment or bonuses, or the possibility of attackers using reused passwords to access bank details. Cheng *et al.* (2013) suggests that while punishments for poor cyber security behaviour can be beneficial, this will only be the case when the consequences are clearly outlined beforehand, and these results would seem to support this as participants seem willing to change behaviour, if likely consequences are clearly communicated to them.

5.4 What do end Users Think of Game-Based Cyber Security Training Methods?

Overall, the opinions of game-based cyber security training were quite positive. Some of the responses distinguish between different types of game-based training, with one respondent stating that puzzle-solving does not "particularly interest or motivate" them. Different types of games will engage different groups of users and a particular area of further study will be to categorise different genres of games and determine how they impact on learning and behaviour change. As previously discussed, a potential advantage of game-based learning is the ability to simulate cyber incidents, to provide practical experience, and to demonstrate the consequences in a safe environment. The responses for game-based methods specifically were limited, but they were generally in line with these reasons, as well as an increase in engagement, complementing the general result that existing training is not engaging (Haney & Lutters, 2018).

6. Limitations and Further Work

Cyber security behaviour among the sample was reasonably good, but there may be flaws with the method in which this conclusion was reached. All factors were weighted equally, with no context considered in the analysis.

For example, a participant who always uses the same password for all sites, but otherwise acts securely, will receive a very strong behaviour score. Each aspect of behaviour could be considered separately, though this would increase the volume of analysis necessary, and increase the likelihood of extreme results. With a larger sample size, it may be reasonable for a future study to focus specifically on password behaviour (for example) and take the overall risk of behaviours into account.

There was no training for participants to complete – the survey was entirely focused on training that participants had done in the past. As there is no way to analyse all the training they took, it is impossible to determine which techniques were used in the training. A more in-depth study could ask similar questions of a pre-determined training exercise, or even use pre- and post- training questionnaires/tests to attempt to determine behaviour change.

The responses themselves were self-report in nature – meaning bias and misunderstanding may have skewed the results. Future data collection would be strengthened if collected through another method, such as by a neutral observer, or through performance-based assessment through some tool.

As has been previously stated, the sample size in this case was quite small. Larger and more varied sample sizes would permit a more detailed analysis, with richer conclusions. Nevertheless, the results obtained show evidence that game-based cyber security training can address many of the issues that exist within cyber security training currently. Future work will aim to expand on this, by investigating which specific aspects of games are most well suited to cyber security training and considering what aspects of existing training are the most significant barriers to behaviour change. Several correlations were found, but there is no data that would encourage drawing any causal relationships. As many variables were compared against each other, it is quite likely that some level of coincidence would arise.

There was a minimal focus directly on game-based training, with only a single question, and some discussions in later interviews. Nevertheless, it was demonstrated that engagement and enjoyment impact on behaviour, two factors that are often relevant to game-based learning.

Directly following this study, there will be several next steps. Firstly, the various game characteristics that impact cyber security behaviour must be determined. For example, engagement has frequently been mentioned as a possible factor. This information will be used to develop prototype game-based methods, which implement effective methods to change behaviour. These will be tested against traditional cyber security training methods, and the resultant data will be used to develop a set of guidelines for developing game-based training methods that effectively impact cyber security behaviour.

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Media Convergence and Game-Based Learning: Developing a Hypothesis of Film Education for the Post-Media Age

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Abstract: The purpose of this paper is to develop a hypothesis of film education built on a theoretical speculation concerning media convergence between cinema and video games, game-based learning and participatory culture, in the interest of schools willing to introduce the subject in their curricula and try out new educational approaches, embracing the inclusive definition of 'film' adopted by British Film Institute (2015).

Keywords: Film education, Game-based learning, Machinima, Participatory culture, Post-media condition, Transformative play

1. Introduction

The twentieth century was the century of cinema; nowadays, thanks to such a legacy, our culture is mainly visual. Therefore, film education has a long tradition in Europe, made of a variety of experiences, practices and approaches covering the whole sector of education.

However, the place of cinema in school curricula is seldom, if ever, guaranteed; when luckily it finds its way to formal education, it raises several questions about its right collocation in the curriculum, the content to cover and the pedagogy to adopt (Burn, 2016).

These issues reinvigorate the ongoing debate about school, with the institution suffering a loss of centrality in young people's lives and having to face the challenges coming from a more and more demanding and highly technological society. As widely known, these days the aim is to build a bridge towards the world outside and make students key players of their own learning; leveraging their media culture can be relevant in this action.

Through the example of Italy, with its school reform making film education a strategic key point of innovation, this paper will take the opportunity to lay the theoretical foundation for an experimental hypothesis of film education.

2. Film Education as a Field of Experimentation and Innovation

In 2012, *Screening Literacy* (BFI and EC, 2013a, 2013b, 2013c), the first European report on film education aimed at framing the state of the art across the Old Continent (Moraldi, 2018), pointed out three main issues, specific as well as strictly interconnected, to tackle in order to proceed towards a common idea of the discipline: cinema as a proper subject rarely has its place within school curricula; a supposed ideal canon of movies (constituting a shared European film heritage) for students to discover and appreciate can't be too exclusive and has necessarily to deal with young people's own cinema culture; in the age of digital filmmaking and convergence culture, the relation between cinema and the other media is inevitably reflected in the approaches to the subject, with a strong emphasis on the creative dimension of media education (BFI and EC, 2013a).

Film education is a "Janus-faced discipline" (Burn, 2016), looking at once at the past and at the future: when cinema is mainly conceived as an art to preserve, it has its own selection of authors and movies to know and fosters an interest in the so-called grammar of film; otherwise, when the focus is on the technological aspects of the medium, especially the ways digital technology affects the processes of creation, editing and distribution of moving images and the concept of author, there's an emphasis on the creative as well as democratic nature of contemporary visual communication.

From an educational perspective, this twofold approach to the subject contains two ways of conceiving the roles of teachers and students and the nature of learning processes: in the first case, cinema seems to be regarded as a fixed knowledge domain, animated by some sort of protectionist spirit towards an elitist idea of art, which film educators embody as the established repositories of culture to transmit; in the second one, a broader perspective on cinema is adopted, with film education embracing popular movies and building bridges towards young people's own media culture to discover and creative practices to leverage. The tension along these two opposites reflects the current transition from the traditional teacher-centred learning model to a more student-centred one.

Film education lacks a unique and shared pedagogical model to follow unlike other well-established disciplines; far from being a flaw and a limitation, this aspect represents how this subject can be lively and open to experimentation and innovation.

In 2015, the British Film Institute published *A Framework for Film Education*, a document aimed at leveraging the variety of practices and experiences related to film education and interpret them in terms of shared learning outcomes, to overcome distances between specific models. The general goal to achieve through film education is a sort of lifelong film learning, with the word 'film' being representative of all kinds of moving images, aligning with the complexity of the contemporary audio-visual landscape (BFI, 2015).

Under the traditional tripartite architecture of media education (Burn and Durran, 2007), with its creative, critical and cultural dimensions, the *Framework* defines more specific learner profiles to develop and foster as learning outcomes, resulting from processes and practices young people are involved in while participating in film and media culture. The ones related to the creative dimension reflect the current phenomenon of viewers becoming makers, thanks to digital technology impacting on film and media making, and are extremely relevant when school tries to build bridges towards the world outside (with its informal education sites), by leveraging students' previous knowledge, competences, social and cultural practices.

The tension which animates the contemporary film spectator, who is at once both viewer and maker, can resolve the distance between theory and practice and makes the creative dimension a strategic link across the critical and the cultural ones.

3. Film Education in Italy

Italy has a long tradition of film industry. Since the silent era, the country has given birth to worldwide recognised directors, actors, screenwriters and important film movements and genres such as Neorealism and Italian-style Comedy. Despite such an important heritage, film education has always had to struggle for acknowledgement within school curricula.

Luckily, thanks to illuminated educators with a vivid passion and forward-looking policy makers, there have been relevant exceptions to this situation, some worthy of attention because of their scale and pedagogy adopted.

The already mentioned twofold way of conceiving film education is well represented by two major national plans to include cinema in formal education which have taken place in the last twenty years (Costantino, 2005; Moraldi, 2018). In 1999, an ambitious three-year project aimed at introducing all students to Italian and European acknowledged film heritage and contain the excessive power of American mainstream cinema, by teaching them film language and storytelling through the tool of film analysis (Medici, 2002).

In 2015, the so-called *Buona Scuola* reform promoted film education in school curricula once again, through a strategic synergy between the Ministry of Education and the Ministry of Culture[1], the latter funding the activities (Moraldi, 2018). The main goal of this ongoing project is to form an aware audience, in a world where media are "onlife" (Floridi, 2017) and the condition of audience is natural to everyone (Fanchi, 2014) by now.

Visual culture is finally perceived as having its own importance; young people's own media practices have to be nurtured.

In terms of media education, there is an emphasis on the creative dimension, which usually results in making audio-visual products by students.

In 2022, this project embraced videogames and animation as subjects to cover[2], in line with a more inclusive meaning of the word 'film' (BFI, 2015) and a democratic attitude towards students' media culture (Buckingham, 2003).

In a sense, film education has just started to be framed in relation to digital technology as a complex phenomenon, absorbing the technological change of cinema as a medium.

4. Learning in the Post-Media Age: The Post-Scholastic Condition

Media scholar Ruggero Eugeni (2015) uses the label 'post-media condition' to describe the contemporary mediascape and the way people live and deal with it. Three great narratives (*epos*) represent not only how media

[1] https://cinemaperlascuola.istruzione.it/wp-content/uploads/2022/12/CIPS-NATIONAL-CINEMA-AND-PICTURES-PLAN-FOR-SCHOOLS.pdf

[2] https://cinemaperlascuola.istruzione.it/wp-content/uploads/2022/03/Piano-Nazionale-Cinema-e-Immagini-per-la-Scuola_22-23.pdf

work and reflect on their working in this condition, but also the ongoing tendencies by users: the *epos* of naturalisation, the *epos* of subjectivation and the *epos* of socialising. They are interconnected and each of them tells something specific about us in relation to media and the way they affect our lives.

The *epos* of socialising is key to the aim of this paper: it describes the tendency to be sociable and establish various interest-driven relationships (Ito et al., 2010, 2008) by people through several kinds of social networks available, leveraging the akin concepts of participatory culture (Jenkins et al., 2009) and affinity space (Gee, 2013).

From an educational perspective, this *epos* leads Eugeni to reflect on the impact of digital media on school system and develop a comparison between formal and informal education: the latter is represented by the emerging participatory culture related to mass media and focuses mainly on developing more practical competences and skills. In terms of learning processes, there is a shift from learning individually to learning through the involvement within a community driven by an affinity. Learning is situated and stems from collaboration and extended practice within social networks.

Video games seem to be the perfect "training camp" (Eugeni, 2015) where such learning can take place and people learn how to stay in the contemporary media-led society.

The socialising aspect of this medium has its own educational implications: from this perspective, it succeeds in promoting situated learning, engaging players and freeing their creative skills where traditionally school fails because of its rigid commitment to theory, transmission of knowledge and teacher-centred learning.

By virtue of this educational potential, linguist James Paul Gee (2014, 2013) has established his own approach to video games, which is not tackled as mere technology, but in terms of communication and literacy processes resulting in social affiliation. His specific interpretation of game-based learning is built on the concept of semiotic domain.

5. Beyond Content's Dictatorship: Learning in a Semiotic Domain

A key aspect of Gee's educational approach to video games is the concept of semiotic domain, that is

> *[…] any set of practices that recruits one or more modalities (e.g., oral or written language, images, equations, symbols, sounds, gestures, graphs, artifacts, etc.) to communicate distinctive types of meanings. (Gee, 2014)*

Gee goes beyond the traditional idea of word-led literacy and adopts the broader perspectives of Multimodality and Social Semiotics (Kress, 2010; Kress and van Leeuwen, 2006; van Leeuwen, 2005; Kress, 2003) to describe the complexity of contemporary communication. He rejects the "content fetish" as the way of conceiving learning and knowledge in school: disciplinary contents are not to be seen as "bodies of information", that is theory detached from the real world, but as "things people do with […] those bodies of information and the various sorts of tools and technologies associated with them." (2004).

The kind of learning in a semiotic domain is active and entails producing and communicating meanings in several modes.

One way to approach this concept is through an inner perspective: what the specific semiotic domain is about; another one is through an outer perspective: what people involved do around this domain, while acting in the related affinity group (Rivoltella, 2013).

Learning also needs to be critical: learners have to reflect on the specific semiotic domain they are in as a system with interconnected parts and processes, the way it is organised and works, and try to innovate it when possible.

Semiotic domains are design spaces that manipulate us as well as we can manipulate them (Gee, 2014). As such, they are always designed by someone and have design grammars, that is working principles, both internal and external, consistent with the two perspectives described previously: the former show the aspects which make the content recognisable; the latter highlight the affinity group which rises by virtue of the semiotic domain, with its social practices.

These design grammars are interrelated and people can contribute towards their design: by subverting the way of experiencing a semiotic domain, they can affect and transform it, or give rise to a new one. The shift of acting within a semiotic domain marks the shift from active to critical learning (Gee, 2014).

Video games are a family of semiotic domains, articulated in several genres, where gamers, usually grouped in game communities, learn and become literate by playing and interacting with each other. The related kind of learning is active by its own nature (Juul, 2011).

Gee (2014) highlights that the educational potential of video games lies in their inner architecture as well as in the network of social relations around them. Playing video games goes beyond the mere dimension of entertainment, though important, and becomes learning how to move within the semiotic domain, interacting both with the medium and the other people involved.

6. Manipulating the Semiotic Domain of Video Games: From Playing to Filming

If gameplay represents the experience allowed to gamers by game designers (Egenfeldt-Nielsen, Smith and Tosca, 2016), using the game engine as a filmmaking tool is the emblem of the way people can manipulate such a design space. This is the case of machinima, that is "making animated movies in real-time with the software that is used to develop and play computer games." (Lowood, 2006).

This media form was born in the '90's, around the then rising first-person shooter video games and thanks to the appropriative and subversive action of gamers towards the medium and its technology. *Doom* (id Software, 1993) institutionalised the 3D space, navigable by gamers through their avatars from a subjective perspective, and established this feature as a new way of conceiving video games and the related gameplay (Fassone, 2017); it was meant to be as an open work by its software house, allowing gamers to modify, personalise, in a word co-create, it, according to the principle of cultural economy (Manovich, 2002).

Quake (id Software, 1996) preserved and amplified this aspect, allowing gamers, then grouped in clans, to appropriate the medium radically to the point of altering its own interactive nature: they started to shoot movies about their performances inside virtual worlds, as a demonstration of playing skills, by using the game engine as a filmmaking tool (Fassone, 2017). The shift from user as a gamer to user as a filmmaker was marked by changing the camera position through "recamming" (Salen and Zimmerman, 2004), that is abandoning the first-person shot for an independent view.

Since then, machinima has quickly risen in popularity, at first inside the clans strictly related to first-person shooter games, then exceeding the genre boundary and embracing a more composite kind of game community, articulated in different gamer profiles, thanks also to the attention to this phenomenon by forward looking game designers interested in the concept of user-generated content (Egenfeldt-Nielsen, Smith and Tosca, 2016).

Machinima can be framed from two perspectives relevant to the aim of this paper: the game design perspective and the animation perspective.

7. The Game Design Perspective: Machinima as Transformative Play

In their framing game design, Katie Salen and Eric Zimmerman (2004) put the words 'play' and 'game' into relations: the former defines a "free movement within a more rigid structure", while the latter points out "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.". According to this lexical distinction allowed by English, a game can be seen as a subset of play because, thanks to its rule, it represents a formalised kind of play; at the same time, play can be seen as a component of game because the player, in order to succeed, has to find their own way through the constraints a game imposes. The tension between these two aspects is what characterises the gameplay as the interaction between the player and the game as a design space and makes the resulting experience challenging and entertaining.

Hard to define as demonstrated by historian Johan Huizinga (2002), play is only thinkable and understandable in terms of opposition to a more general order as a rigid structure, whatever form the latter takes.

Play is also unpredictable, able to change the game which contains it. This occurrence is defined as transformative play and the use of a game engine as a movie-making tool is an example of it (Salen and Zimmerman, 2004).

By leveraging this aspect, players can change the game experience (Salen and Zimmerman, 2004), whether or not allowed to do it.

In relation to *The Sims* (EA, 2000-), Gee and Hayes (2010) speak of gaming beyond gaming to describe the experience of going beyond the traditional gameplay which takes place in the affinity spaces channelled by the web; in Gee's own words, "Everyone can, if they wish, produce and not just consume" (2013).

This creative agency results in an innovative form of cultural production, which Jenkins (2007) defines "grassroots", that is coming from media users through media appropriation, and characterises youth practices in the media ecology; the resulting learning is based especially on the genre of participation, which can be interest-driven and centred on specialising activities (Ito et al., 2010, 2008).

Therefore, the idea of game-based learning is constructionist instead of instructionist (Whitton, 2014): learning is not developed through transmitting and consuming educational content via video games previously conceived by designers, but it stems from the horizontal interaction between members of social affiliations and their sharing of knowledge and competences as well as their production of contents and artefacts.

This approach to game-based learning marks the shift from the learners as players and consumers paradigm to the one of learners as creators and producers.

8. The Animation Perspective: The Return of the Impossible Image

Machinima can be seen as a particular form of animation, halfway between digital automatism due to computer procedurality and analogue manual skills through mouse and keyboard, but first and foremost a strong commitment, required to "machinimators" (Kelland, Morris and Lloyd, 2005) in order to leverage the game engine and carve new audio-visual artefacts from video games.

At the end of the 19th century, cinema soon established itself as the only art able to fully represent reality in a truly objective way: photography was completed with movement.

If animation as a concept was central to the rise and development of cinema as a medium, on the contrary, precisely as a form of cinema, it was soon dismissed as a low expression of the then new art by a growing derogatory attitude.

In his framing cinema from the perspective of multimodality, Burn (2017, 2016) recalls the trajectory descending from the anti-realist Georges Méliès' movies, where magic was lent to the medium and the resulting composite images could create the world of unreality, or represent the impossible.

In a sense, visual effects started with this premise and Méliès can be considered the father of modern computer graphics (Manovich, 2002), where machinima belongs to.

This media form, thanks especially to lamination, which in animation refers to the semiotic process of creating images through the stratification of signifier material (Burn, 2017, 2016), brings cinema back to its own origins and makes it rediscover a neglected tradition.

9. Innovating Film Education: The Machinima Hypothesis

From a pedagogical perspective, there are two main approaches to formal film education, one theoretical and one practical, which have been embodied by critical analysis and filmmaking (Felini, 2015). Traditionally, they have been conceived as separated, with the former particularly widespread at the beginning and the latter which started to grow in importance especially in the 90's, thanks to the miniaturisation of cameras and the introduction of non-linear video editing software. Nowadays, it is possible to overcome the distance between theory and practice by leveraging the affordances of digital technology and adopting innovative approaches to film education already circulating in Europe.

According to Matthew Thomas Payne (2011), the educational potential of machinima is clear: it makes possible to foster the three dimension of media education. The resulting approach to the field recalls Jean Piaget's theory and its emphasis on learner-centred knowledge production based on discovery and experience. Machinima is an aware act of appropriation towards a medium and its technology, therefore, when it is adopted as a learning tool, the related pedagogical approach is based on practice: the media form is associated to a pedagogy of craft because of the tinkering with technology which characterises it (Ng and Barrett, 2013).

This aspect does not ban theory from learning: the former is developed deductively through experience (Buckingham, 2003); therefore, expertise can be seen as a sort of unspoken theory people already possess thanks to experience and perseverance (Gee, 2014). While creating machinima, the act of redrafting is emblematic of a constant shift from action to reflection according to a specific expressive goal of the machinimator who, as an apprentice in a hand-crafted studio (Antinucci, 1999, 2001), learns by making, masters the art and finds their own voice at the end.

By including machinima in film education, it is possible to nurture students' media skills and culture as well as to refine and expand them by introducing people to acknowledged visual communication models. For this reason, Alain Bergala (2016) states that "The [film] analysis is not an end in itself, but a movement toward something else.": it does not teach students how to read a film, but it inspires and prepares them for practice. Thanks to the concept of creative analysis (Bergala, 2016), the bond between theory and practice proves to be effective in the so-called pedagogy of fragment, which works through exposition to and confrontation between different models, leading to their assimilation within the range of expressive solutions at one's disposal. In this sense, the creative process is both practical and critical.

Machinima might be the right place where let this confrontation take place in an innovative way.

10. Finding Virtual Reality: The *Casablanca Interactive Performance Experiment*

The founding act of machinima as a new approach to film education could be traced back to the *Casablanca Interactive Performance Experiment*, led in 2002 and 2003 at the University of Cambridge (Nitsche, 2008; Nitsche and Thomas, 2004). The aim of this experiment was to interpret an acknowledged communicative model such as the Classical Hollywood Cinema, in light of the affordances offered by virtual reality which then had just started to be explored as a new media form, in order to prove the expressive strength of this interactive medium and create an experience for the audience as engaging as the one allowed by cinema.

In 2002, the students involved in the project had to recreate a famous scene from *Casablanca* (Curtiz, 1942) - the one set in Rick's apartment when Ilsa admits she still loves him - through the use of *Unreal* game engine. The participants, who had previously watched the movie (without the scene to reproduce in order to avoid any kind of influence) and read the script, were organised in small groups. They had to interpret the fragment in light of their understanding and own media culture, then implement it in the virtual environment (Nitsche and Thomas, 2004).

In terms of style, the resulting performance of the camera was determined by the extemporaneous interaction between the operator and the acting characters; despite the previous planning, the camera work had to adapt to the freedom allowed by the virtual nature of the medium, with no spatial restrictions, or due to film conventions, in a way which was closer to Dogme 95 movies (Nitsche, 2008).

At the same time, the new medium also imposed its constraints on several aspects of production: specific camera movements were not allowed (Nitsche and Thomas, 2004); characters acting was determined through customized puppeteering (Kelland, Morris and Lloyd, 2005) by students practice and improvisation, in part affected by automatic animation of the game engine own procedurality (Nitsche and Thomas, 2004).

If *Casablanca* set the style, the *Experiment* resulted in a combination of personal choices shifting from classic to modern cinema, with a rich cinematic vocabulary deployed (Nitsche, 2008; Nitsche and Thomas, 2004) and the possibility to create and develop all the expressive material required from scratch.

11. Virtual Filmmaking in Education: Machinima into Practice

In the last two decades, some machinima projects have been carried out, across school and university at international level, under the supervision of educators and researchers.

Far from setting acknowledged patterns to follow and being prescriptive, these projects, through their explorative nature, can offer useful insights into different questions related to film education: the correct use of film language combined with creativity in digital filmmaking (Davis *et al.*, 2013); the multimodal nature of cinema (Burn, 2016, 2017); the deployment of virtual worlds as virtual classrooms (Benassi, 2012b; Carter, 2012); nevertheless, they can also be specific and show, for example, how a university film production online course can be developed through virtual reality (Ziemsen, 2017), or smaller in scale, how a short movie might be shot in virtual worlds at school instead of having traditional filmmaking (Benassi, 2012a).

The urge to innovate film education in light of digital technology is getting more and more relevant. These projects prove the importance virtual worlds have started to acquire in terms of media education and education in general ('metaverse' is the new buzzword); they also highlight the fact that a new approach to film education, hopefully closer to young people's media culture, can find its own space among other more traditional practices.

Hands-on learning, creativity and participation are the key aspects of such an approach, in line with the guidelines of the *Framework*. Teaching goes beyond knowledge transmission: it makes knowledge possible to build and acquire through situated discovery and shared experience. The focus is on learning processes resulting

from the affordances of technology as a way to appreciate how film literacy changes through technological evolution and related people's practices.

Given machinima as one of the trajectories of moving images, this new approach needs to be inclusive and explorative, with such a media form strategic in terms of complementarity within visual culture.

12. Conclusions

Machinima can be seen as a peculiar trajectory of moving images in the digital age; as such, this media form lies in a sort of Janus-faced condition of its own: it looks to cinema for a precise narrative model to follow (Salen, 2011) as well as it exposes the artistic nature of image creation through digital authoring technology. As Peter Greenaway (2010) provocatively states, the latter can free machinima from the constraints of storytelling in favour of the expressive power of images, succeeding where cinema has failed.

This dichotomy happens to emerge also in the field of film education, where usually film language and storytelling represent the main interest towards cinema to the detriment of other relevant aspects of the medium, such as image composition, acting and *mise-en-scène*.

In his film education hypothesis, not only Bergala (2016) bends the boundaries between theory and practice, but also rethinks both in an innovative way of mutual interrelationship, which adheres to the media learning dynamic model of action and reflection outlined by Buckingham (2003). By leveraging film excerpts, creative analysis aims to put students in a film director's shoes, in order to reflect on specific aspects and prepare them for practice; the latter can result in a fragment to shoot, when decision making process takes place and all the expressive materials of cinema can be explored, free from the urgency of coherence and cohesion a whole movie entails from a narrative standpoint.

The *Experiment* shows how this dichotomy might be solved when machinima is used as an approach. Analogue craftsmanship and digital procedurality live side by side in this media form, each time making virtual worlds design spaces manipulating as well as to manipulate. By re-interpreting a famous scene from *Casablanca*, the students had to reflect on a specific way of communicating, appreciate it in order to explore then the expressive means of a virtual environment.

By enucleating an excerpt from the rest of the movie, it becomes unfamiliar by virtue of its detachment, therefore captivating to discover in depth and make it familiar from an inner perspective. When moving the fragment to a virtual environment, the shift from critical to creative analysis happens under a ludic regime: the restrictions of the interactive media act as the rules of a game and make the design space manipulating and open to manipulation as well. At the same time, people have the opportunity to interpret the movie through the lens of their own media culture and their understanding of the original text.

Machinima filmmaking can be a hypothesis to take into account as "[…] an example, not of disjuncture or radical practice, but of bridge-building" (Burn, 2016) in terms of media education, through which it could be possible to discover how the concept of (film) literacy is destined for a change from the perspective of young people (Buckingham and Sefton-Green, 2017)

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UnlockArt: Cultural Mediation at the Museum Through an Augmented Reality Escape Room

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Abstract: In the context of a museum, cultural mediation facilitates access to the works of art for the visitors which not always share the culture the pieces of art come from. Tools and resources such as catalogs, guided tours, or the work of the curators are all part of the museum's cultural mediation, which highlights and informs the visitors of the works on display. In this case study we present the game design process and results of UnlockArt, a project developed as a cultural mediation tool at the Museo delle Culture (MUSEC) in Lugano, Switzerland. The project studied and applied the educational escape room format to enhance the museum experience for visitors, and to encourage the younger ones to approach the collection through a ludic activity. By the means of the Star Model (Botturi and Babazadeh, 2020), the project designed an educational escape room for the "JAPAN. Arts and Life. The Montgomery Collection" exhibition, a collection of Japanese objects from the period between the 12th and the 20th century. Educational escape rooms are a format that works well in class, but may be burdensome to apply in a museum, which intrinsically imposes many constraints. Players should be silent, the escape room should always be ready to be played and easy to be rebooted, and it should not impact the exhibition for visitors that wish not to engage in the experience. For this reason, we opted for an augmented reality educational escape room (AR EER) which can be played on tablets. Such approach only requires QR codes placed around the exhibition, which hide puzzles and hints tied to the works exhibited in the museum, and does not need any rebooting phase as the puzzles are to be solved in augmented reality.

Keywords: Cultural mediation, Museum escape room, Augmented reality, Game design

1. Introduction and Background

UnlockArt is a project at the intersection of cultural mediation and game-based learning through Educational Escape Rooms (EER).

Cultural mediation is the act of mediating the access by people from a culture (e.g., Western European) to a different culture (e.g., Japanese). In the case of a museum, cultural mediation takes the form of catalogues and brochures, guided tours, and the work of the curators while preparing an exhibition.

The concept of EER has been broadly studied in the past, with a vast body of research ranging from kindergarten to higher or adult education (Fotaris and Mastoras, 2019). EERs are usually played in class, with medium-to-large groups of players, with well-defined educational objectives and with the teacher/lecturer acting as game master.

In this project we tried to adapt the EER format to the museum context. Such context poses many constraints and differs from both the classroom experience of EERs and the entertaining experience of commercial escape rooms from the point of view of players (number, age, skill level), play areas, locks, learning goals, and entertainment. UnlockArt has been developed to be played throughout an entire exhibition, as the puzzles refer to different works exposed, and had two main objectives:

- Promoting the exhibition through a novel entertaining activity that can be experienced while visiting the museum;
- Providing visitors with more insight on some of the works on display while playing.

Researchers have explored the idea of using technology and augmented reality (AR) within EER experiences to gamify the museum experience in different ways. Koenig et al. (2022) presented a similar work on creating an escape room for cultural mediation in order to foster curiosity in arts and culture by the visitors in a museum. Antoniou et al. (2019) proposed a digital escape room recreating (some of) the museum environments to attract visitors to a peripheral museum which can be played on a Web browser. McFadden and Porter (2018) proposed an AR ER pilot for the Minneapolis Institute of Art, while Vicari (2020) proposed an AR ER designed by the students to be played at the American Museum of Natural History to support astronomy learning using HoloLens.

UnlockArt was developed for the Museo delle Culture (MUSEC) in Lugano, Switzerland from 2021 to 2022, targeting the "JAPAN. Arts and Life. The Montgomery Collection" exhibition, a collection of Japanese objects

and memorabilia from the period between the 12th and the 20th century. The application was developed for tablets that were distributed when visitors entered the exhibition. Through QR codes scattered around the exhibition, visitors could solve riddles to save Mr. Montgomery from a curse. Quizzes and riddles were tied to the objects exhibited in the museum, requiring visitors to discover and use basic information about what they were observing in order to solve the riddles.

2. The UnlockArt Design and Development

UnlockArt was born as a cultural mediation project with *Museo in erba*[1], a museum in Lugano, Switzerland, which offers interactive exhibitions and laboratories for kids and young adults. The project aimed to develop an AR EER for the Museo delle Culture (MUSEC) in Lugano, one of the most important museums of the city, as a cultural mediation tool. The main idea was to develop an entertaining and exciting activity in a novel format in order to attract new, and – especially – young visitors, which so far represented only a minor share of the museum's visitors. The escape room format was found to be an exciting and fun way to live the museum experience through an overarching narrative and riddles related to a specific exhibition. Yet, this format is not really suited to be played in a museum: hiding riddles, locks, and hints among expensive pieces of art may be difficult as participants may mistake a piece of art for a part of the ER. Moreover, the experience should not tamper the exhibition itself, and more importantly other visitors that may want to enjoy the experience without playing the ER. Locks may be opened and never closed, thus other participants may arrive and find open locks and already solved riddles, or hints could be moved or taken away, making it impossible by other players to finish the experience and cause frustration.

For these reasons we opted to design an AR EER using a software that was developed during a Master thesis at our university (Geronzi 2020). The first part of the project (May-November 2021), aimed to design the EER given the constraints and the software capabilities. During the second part of the project (November 2021-June 2022) the software was updated and new puzzles were added as a support for the designed EER. The museum EER finally launched in September 2022 and was kept available until January 2023 at the museum.

2.1 The Design Phase

The design of the experience was based on the Star Model (Botturi and Babazadeh, 2020) (Figure 1) and was developed from May 2021 to November 2021. The learning and the narrative were designed by the Museo in erba, which was given the theme of the exhibition with images of the object that would be displayed. We then helped integrating the puzzles, to be sure to produce effective puzzles that stimulated the learning of facts and anecdotes regarding the exhibited objects. The game-flow and the equipment were part of the constraints of playing an EER in a museum.

Before starting with the design of the actual elements, we performed an analysis of the context elements of the escape room: players, constraints, debriefing, and evaluation.

2.1.1 Context elements

Players. Our aim was to build an accessible activity for cultural mediation that would be exciting for kids and adults and that would attract more visitors to MUSEC. For this reason, we decided to aim for a fun narrative, which would not result boring for young adults and adults, and have puzzles that could be tricky to solve. To help less skilled players we decided to implement a hint system (which was not yet implemented in the AR ER platform) within each puzzle. Given the fact that multiple players would be playing the escape room in series, we decided not to have puzzles that required to move QR codes around: each puzzle was tied to a single QR code, which was hanged to the walls of the exhibition.

Constraints. Given the nature of the museum, we had many constraints to keep into account before starting the actual design. The main constraints revolved around the fact that we wanted an experience that could be *lived* while visiting the museum. For this reason, we could not aim for a standard escape room with padlocks and locked doors because that would tamper the experience for other players if there was no Game Master ready to reset all the locks. This could create bottlenecks and frustration for the standard museum visitors. The AR nature of the chosen solution allowed us to design an experience that does not need a Game Master to reset the room, because all the puzzles would be solved on a portable device. Moreover, we decided not to have a timer in order to avoid players running around the exhibition to find clues and missing pieces of

[1] https://www.lugano.ch/vivere-lugano/cultura-e-tempo-libero/musei/museo-erba/

information, ruining the experience for themselves and possibly to other visitors that decided not to play the game.

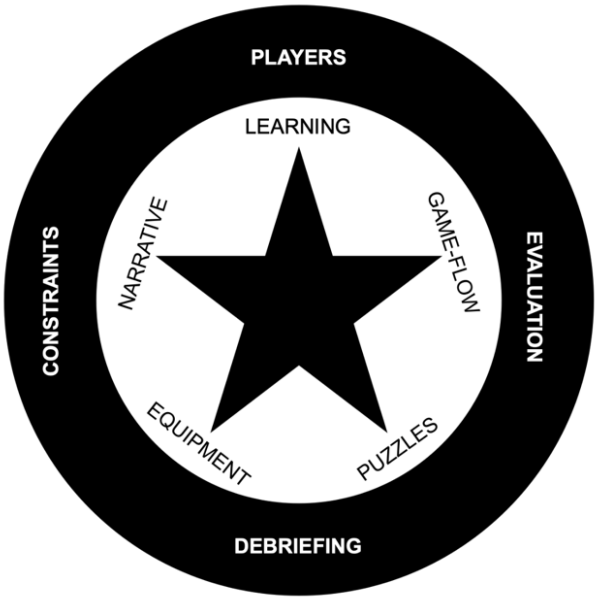

Figure 1: The Star Model for educational escape room design (from Botturi & Babazadeh, 2020).

For this reason, we also refrained from designing and integrating sounds in the experience. To avoid problems with application compatibility we decided to distribute the application on ten tablets available at the university and lend them to the museum. The number of tablets turned out to be sufficient as not more than 7-8 (groups of) visitors per round requested to play the experience. Once the visit was over, it was sufficient to close and reopen the app for the next players.

Evaluation. In order not to further inquire the visitors, it was decided not to prepare a post-experience survey for the participants. The players were informally asked about their experience by the museum staff at the end of the visit and some informal feedback was gathered and shared with the researchers and the Museo in erba staff.

Debriefing. We planned no debriefing for the activity, as that would have been unnatural in the museum setting. The debriefing was implicit in the application, which included an in-depth description of the solutions with respect to the associated pieces of art.

2.1.2 Design elements

Narrative. The narrative describes how the owner of the collection, Jeffrey Montgomery, has been possessed by a *tanuki*, a Japanese supernatural being. The only way to save Jeffery Montgomery is to find all the pieces of a kimono that, once wore, will free him from the tanuki. The pieces of the kimono will be unlocked as the puzzles are solved and stored within a virtual backpack. The last puzzle will require the players to have collected all five pieces of the kimono that will be used to solve the puzzle. The kimono puzzle is tied to a real kimono displayed in the exhibition, as other puzzles in the EER with respect to other pieces of art.

Learning. By tying the puzzles to elements of the exhibition, players needed to understand what they were looking at during their visit in order to solve the puzzles. For example, the kimono puzzle needed the players to closely look at the real kimono shown in the exhibition in order to put its pieces together (Figure 6). Visitors were given a brochure at the beginning of the visit: this brochure also contained helpful information to solve some of the puzzles. Players were invited to play while visiting, but also taking into account the information in the brochure. At the end of every puzzle, an in-depth description of the related piece of art was offered for participants that were curious to know more.

Puzzles. The puzzles were all related to the art exhibited in the museum. For example, besides the final kimono puzzle, one puzzle asked to find the differences between a piece of art shown in the exhibition and a version that has been modified by the tanuki on the app. The player had to look closely in order to find the differences

from the original (Figure 2). One puzzle required to decipher a *haiku* (a Japanese form of poem), another asked to discover the materials an exhibited backpack was made of. Other puzzles were related to counting a certain number of elements within exposed art, or assign the correct object to its everyday usage. To solve the puzzles, it was sufficient to carefully read the label description, or the brochure information. The puzzles fit in the narrative through the tanuki gimmick: the tanuki was making a mess in the collection of Jeffrey Montgomery, and players were tasked to fix the mess while looking for the pieces of the precious kimono.

Figure 2: The piece of art showing horses with some errors to be found

Game-flow. We opted not to have a complex branching or open game-flow (Nicholson 2018). The museum exhibition was linear, thus we decided to opt for a linear and straightforward game-flow, aligned with the exhibition flow.

Equipment. The only equipment needed for the EER to be played were QR codes which were hanging on the walls of the exhibition, nearby the pieces of art which the puzzles were associated to(Figure 4). The exact position of the QR codes was decided with the curator of the exhibition, in order not to interfere with non-playing visitors.

Once the design phase was done, in November 2021 we started the development of the missing features in the AR ER application.

2.2 The Development Phase

The starting application, developed within a Master thesis in 2020 (Geronzi 2020), presented a simple subset of puzzles which could be used in a Web application which helps users develop their own AR (E)ERs. The application offered multiple-choice puzzles, password input, but also puzzles related to the order or position of QR codes, which we decided not to use. The required features analyzed during the design phase included:

- A new graphic skin for the application, Japanese-themed (Figure 3, Figure 4);
- a drag-and-drop puzzle (Figure 4);
- a "find the differences" puzzle (Figure 2);
- an "in-depth" button that let players know more about the puzzle they just solved;
- save-state of the game (if players would mistakenly close the application);
- hints system;
- English translation (Figure 3).

The development of the functionalities was done during Fall semester 2021 within the context of a Bachelor thesis and one semester project, and during Spring semester 2022 within a semester project done by two students. A total of four students worked on the above-mentioned improvements needed for the application to be used within the museum.

The application was originally developed using the Unity real-time development platform for the application side, and PHP for the Web application where users can generate their own (E)ERs. The Web app has been revamped in a recent Bachelor thesis, and now runs on Node.js. The AR EER for the museum has been deployed on Samsung Galaxy Tab A tablets which were distributed at the museum entrance. Visitors could borrow the tablets to play the escape room and return it at the end of the tour.

3. UnlockArt in Action

Upon starting, the application shows a splash screen with the possibility to change language and start the game, shown in Figure 3. Upon clicking on the start button, the narrative starts with a series of text boxes. Players are introduced to the AR system by scanning a first marker available at the entrance of the museum, which continues with the narrative and only requires the players to press a button. This was done in order for the players to gain familiarity with the system.

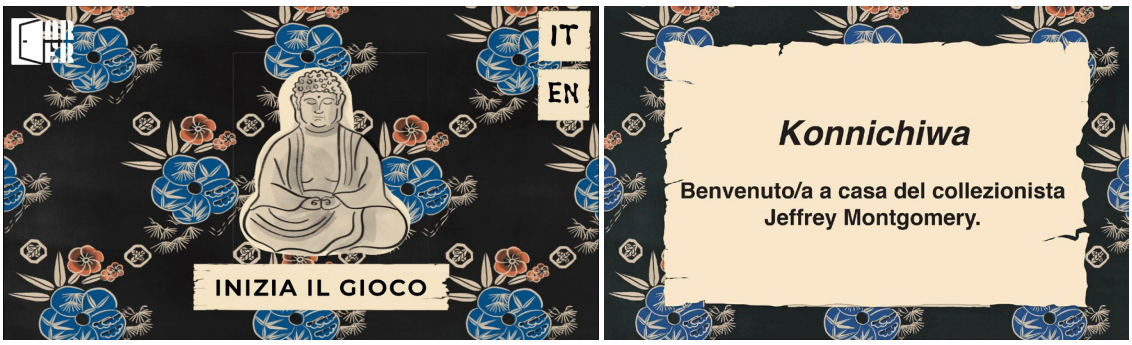

Figure 3: The starting scene of the game, where players can start the game or pick another language. The game then starts with the introductory narrative

The first puzzle was found in the following room, with a marker hanging close to a horse painting (Figure 4). The players were asked to find the differences on the image shown on the tablet with respect to the original.

Figure 4: A player interacting with the horse puzzle by scanning the marker near the painting

In the following room, players could find a series of different shaped backpacks and everyday utensils. The marker hanging on a wall asked the players to find a particular backpack in the room and, through a multiple-choice quiz, tell the material that was used to craft it. The answer could be found on the label of the object or on the brochure visitors received upon entering the exhibit.

In the next room, visitors could find four tall banners and a QR code. The code was hiding a Japanese haiku, made up by the game designers, which was a riddle that could be solved by closely observing the banners.

Near the end of the first floor, visitors could find a plate with a figure engraved on it and a marker. By looking at the brochure, or having paid attention to the previous room with no quizzes, visitors knew the figure engraved on it meant "longevity" (Figure 5).

Figure 5: Player interacting with the plate quiz. The tab shows the multiple-choice puzzle

The first upstairs room had a series of plates showing chrysanthemums, symbolizing longevity and royalty in the Japanese culture. Players had to understand the word for *Kiku* used in the riddle (chrysanthemums) and count the number of chrysanthemums on the plates in the room.

After one QR giving some insight to the players regarding their status in the ER and regarding the room they were visiting, the next puzzle required players to drag-and-drop everyday use objects in 1800 in Japan with nowadays items with the same usage.

The next riddle asked the players to find the number of the *futon* (a mattress) in exhibition given the description of the symbols on it, unlocking the final piece of the kimono. Finally, the final puzzle asked the players to recompose the kimono, that was torn apart by the tanuki, with which players were able to free Jeffrey Montgomery (Figure 6).

Figure 6: The kimono puzzle when all the pieces have been found

The narrative then concluded, inviting the players to tell their friends to try the experience at the museum.

4. Qualitative Feedback and Outcomes

In over a period of 4 months, the EER has been played by more than 2000 visitors and was overall a success. Visitors who experienced the game were happy and positive, and said they would tell their friends and family to visit the exhibition and to try playing the escape room. Players admitted that such an experience helped them to better observe details of the art exposed in the museum, and to be patient and take their time to learn about the various objects on display. Such comments are very important, given that Jeffrey Montgomery himself, the actual collector that owns the objects in the exhibition, used the same approach to pick the items for his collection in the first place. The museum staff was also happy with the outcome of the project and asked if it was possible to set up more escape rooms for future exhibitions that could also target families and young adults. Their hope is to increase the number of visitors to their exhibitions, lower the age range, and open up to families and young adults, as well as increase the engagement the visitors have while visiting MUSEC.

During the exhibition, the local television recorded a television service about the game[2]. Figure 7 shows two frames.

Figure 7: The local television filmed a report of the AR experience at the Museum. The journalist was getting close to the marker in order to solve the horse puzzle in the first image, and was solving the banners riddle in the second

5. Conclusions and Outlooks

In this case study we presented the game design process and results of UnlockArt, an EER project developed as a cultural mediation tool at the Museo delle Culture (MUSEC) in Lugano, Switzerland. The project took approximately a year from requirements to deployment, from May 2021 to June 2022. After a testing phase, it has been deployed in the museum from September 2022 to January 2023, when the exhibition closed, welcoming over 2000 visitors.

The case study showed how to design an educational escape room in a context that is not a classroom, a university laboratory, or a company, but a museum, with a series of very important non-flexible constraints. It also illustrated the design process of an augmented reality escape room in the museum context. While this study only gathered informal feedback and was not supported by structured data gathering an analysis, we believe our work could give some important insights to escape room designers.

Escape rooms are a powerful tool that besides fostering soft skills (Reuter et al., 2020) can also assist the development of subject matter competencies and knowledge. Studies have shown how educational escape rooms can foster such development, with this case study we showed they may also help fostering knowledge that we learn within a museum exhibition. By gamifying the museum experience through augmented reality, we were able to create an interactive and entertaining environment for visitors, which could challenge themselves while visiting the exhibit. Our (educational) escape room can be seen as a cultural mediation tool, which could be applied in other contexts, such as architectural and historical sites.

Our case study also showed how, with the use of technology and augmented reality, we could design and develop an escape room within a set of very strict constraints, without interfering with other people's experience at the museum, yet offering a valuable experience. The key aspects of the design included how, by making use of augmented reality, we were able to skip the reboot phase of an escape room by just restarting the application. Moreover, we have shown how such approach, within the museum context, suits with a linear game-flow, which usually does not work in big classrooms where a branching game-flow works better. The narrative used real elements shown in the exhibition, making it feel more real and not only as a gimmick to motivate the experience. Lastly, by lending the tablets instead of asking visitors to download the application on their devices, we lowered the technological gap that could be intrinsic in such experiences and could be a deterrent for some less technologically-inclined individuals.

Visitors as well as the museum staff were positive about the game and asked for more, highlighting once again the power of this format.

We are planning to work on more experiences of this kind at MUSEC by including data gathering through the application, and more formal feedback by the users, which could help with future developments and studies in

[2] https://www.rsi.ch/play/tv/il-quotidiano/video/il-quotidiano?urn=urn:rsi:video:15792037&startTime=1871 (in Italian)

the field. Open questions on how much the experience helped visitors to learn and how the experience may be conducive to other museum visits could be open questions in said formal feedback.

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A Model for Balancing Clarity and Appeal in Serious Game Visuals

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Abstract: In serious game development, graphic design needs to be eye-catching, while also depicting subject matter content in a responsible, accurate, and clear way. Previous research has shown that abstract and symbolic game visuals seem to be preferable for learning and providing an engaging experience. Our research focuses on describing the challenges involved in creating effective visual communication through game graphics in cross cultures. In particular, we're interested in examining if certain styles of visual communication are more or less effective between different cultural demographics. To examine this, we have created a serious game which aims to promote healthy food and nutrition habits to teenagers in both Nepalese and Swedish schools and by doing so also motivate behavioral changes toward healthier eating habits. We are currently conducting studies to see whether preferences and image recognition differ between the two demographical spheres. This paper will only discuss the exploratory study done in Nepal. Ultimately, this paper aims to contribute development guidelines that can aid developers in creating more effective visual communication in their serious games, and we primarily focus on exploring what we call the compromise of 'clarity' and 'appeal' in the creation of game graphics. We present an initial model for choosing at what level in terms of realism/abstraction and taxonomic hierarchy the graphical components of serious games optimally should be produced in order to solve the dilemma of precise, unmistakable, yet appealing visuals in serious games. It all comes down to two primary decisions: defining the taxonomic hierarchy of the items to depict, and choosing the style in which to depict them. With a better understanding of when different game visuals are more or less appropriate, both in terms of style and in which objects are represented, game developers will be able to balance production costs better while also creating something that strikes the compromise between clarity and appeal.

Keywords: Visual communication, Game graphics, Development guidelines, Cross-cultural serious games, Health, localization

1. Introduction

In serious games, digital game-based learning, and gamification research, discussions and guidelines centering around the importance of achieving a good balance between engaging and informative game mechanics is in abundance (e.g., Kiili, 2005; Groff, Howells and Cranmer, 2012; McClarty et al., 2012; Rai and Beck, 2012). The complexity of both communicating a message in a highly engaging way that keeps the player playing, while still being "true to the message" and not distracting from important issues, is certainly at the core of designing the mechanics and systems of these types of games. However, we argue that the creation of graphics constitutes a very similar challenge. They need to be eye-catching, while also depicting subject matter content in a responsible, accurate, and clear way. If one is to look at the graphics of a serious game from a utilitarian perspective, they should essentially be as verisimilitudinous as possible; after all, the higher fidelity with which an object is depicted, the less room there is for misinterpretation. Furthermore, a higher degree of fidelity should also improve transferability of knowledge from the serious game and the real world (Petridis et al., 2012). As soon as layers of artistic interpretation and stylization are applied to a real-world object, room for misinterpretation of the object grows and players might have a harder time connecting the in-game object and its real-world counterpart.

From a less utilitarian and more subjective perspective, stylization and abstraction is sometimes desirable by the target audience: photorealism, while clear, might not always be appealing. Finding the right balance between clarity and appeal requires significant deliberation from a development team. While there are many guidelines (Yusoff et al., 2009; Arnab et al., 2015; Tsekleves et al., 2016) giving advice on how to balance gameplay and "serious" content, there are few guidelines that give advice on how to strike a balance in a game's visuals.

However, full photorealism is itself problematic (Petridis et al., 2012): it is unfeasible to produce photorealistic assets within most serious game development projects' budgets; development teams might not have the skills required to efficiently produce photorealistic objects; and, most end-user hardware is unlikely to meet specification requirements for displaying those types of graphics. There is also the more ephemeral reason that photorealism might simply be unappealing to certain audiences. So there are both practical and subjective

reasons serious game developers need to compromise between and find a way to stylize what they're representing in the game.

The study presents a model aimed at resolving the challenge of creating visually clear, easily recognizable, and visually appealing elements in serious games. It draws upon existing theories, literature findings, exploratory studies, field studies, and practical development. The model has been implemented in a serious game, and we anticipate that it will assist developers in making more efficient decisions while maintaining an engaging game that fulfills its intended purpose. By establishing the optimal level of object representation within the taxonomic hierarchy and determining the necessary level of fidelity between realism and abstraction, development teams can strike the right balance that aligns with their game's objectives. This approach extends beyond regional specificities and can also be applied to subject matter details on a universal-specific spectrum.

2. Game Visual Development

The game that we're using as a case study for this broader discussion of visual communication in serious games is *Happy Heart* - a mobile game that aims to promote a healthy lifestyle through diet and physical activity (shown in Figure 1).

2.1 Game Project

This project aims to prevent future cardiovascular disease for teenagers aged 13-15 years in Nepal. As the title of the game suggests, the theme of the game is "taking care of your heart" as the basis for the game. The project includes two "teams" - the game development team, and a team of local researchers in Nepal. The Nepalese team has done research to see what knowledge gaps the target player group has, and we have used their resulting Knowledge, Attitude, and Practice (KAP) report regarding heart disease among the target group to address these knowledge gaps through our game design (Shakya et al., 2023).

Figure 1: The screen prints depict the four levels of the serious game Happy Heart, namely food sorter (top left), salt seeker (top right), activity (bottom left), and master chefs (bottom right)

2.2 Game Visual Research Methodology

To achieve the objectives of this study, the methodology conducted three phases thus far: 1) literature review; 2) exploratory study and field study; and 3) implementation of the serious games.

1. **Literature review:** This phase is meant to reveal the broad outlines of visual communication development and use in serious games context. As a result of this phase, we found that research on visuals in serious games is relatively rare, and one common conclusion is that visual complexity distracts students from the intended learning content. When users are presented with overloaded

information, human visual perception works unconsciously to ignore the least visible parts. Thus, we framed the graphic style into an abstract style.

2. **Exploratory study and field study:** An empirical study was carried out by the game development team to explore the visual recognition and preferences of Nepalese teenagers. The team also delved into the participants' video game habits and media preferences to assess their visual literacy. To gain a contextual understanding of the culture and environment, informal interactions were held with students in schools and households.
3. **Implementation of the serious games:** Following the exploratory and field study in Nepal, the game development team collaborated with the Nepalese team to design the game mechanics and visuals. Using findings and theories identified in the literature, exploratory study, and field study as guidelines when implemented into the visual design of the serious game *Happy Heart.*

3. Targeted Issues

The creation of effective and appealing visual communication is a challenge that has been examined by non-game-related research for quite a while, primarily in the fields of UXD and cognitive sciences. In research focusing on website design, for example, studies have been carried out that investigate color preferences and visual complexity in different parts of the world (Reinecke and Gajos, 2014). As an example, a study comparing color preferences between British and Namibian adults stated that: “We suggest that not only do patterns of color preference vary across individuals and groups but the underlying mechanisms and dimensions of color preference vary as well. The findings have implications for broader debate on the extent to which our perception and experience of color is culturally relative or universally constrained.” (Taylor, Grandison and Franklin, 2012). These types of studies are, in our view, highly relevant to the field of serious games. However, visual preferences are an issue that is seldom explored or taken into account in the development of serious games where discussions of the merger of informative content and gameplay mechanics often take center stage.

This “lopsided” focus of serious game research leads to game developers primarily just creating “serviceable” graphics as a general afterthought to suit the game’s general theme. However, the creation of “good” serious game graphics comes down to a series of decisions that share similarities with the creation of “good” game mechanics. While game designers are concerned with balancing learning and engagement, artists need to be concerned with clarity and appeal. In addition to that, artists also need to take demographic characteristics and peculiarities into account.

By visual ‘clarity’ we refer to how recognizable the game object is as a representation of its real-world counterpart. As previously mentioned, the extreme example of a clear visual style would be full photorealism. A fully realized, high-resolution 3D render of a real-world object would be very quickly recognizable by a player. As we move towards the opposite end of the clarity spectrum we find more and more stylized imagery (more cartoony or hand-drawn styles, or pixel graphics), and ultimately approach something akin to abstract art.

Furthermore there is the obvious practical issue of full photorealism being far outside the scope of most serious game projects either due to budgetary constraints, capabilities of the game engine, as well as the expertise of most development teams. This can also be described as visual fidelity, however we find the term ‘clarity’ to be more useful since it leaves less room for miscommunication as fidelity can also relate to technical properties of an image (e.g., its resolution).

4. Solution: A Model for Balancing Clarity and Appeal

Solving the dilemma of clear, unmistakable, yet appealing visuals in serious games comes down to two primary decisions: choosing the taxonomic hierarchy of the items to depict, and choosing the style in which to depict them. In cross-demographic contexts, it is crucial for developers to give thorough consideration to visual representation, as it has the potential to influence the adaptation of the target group.

It is also important to note that the aforementioned challenges involved in creating appealing visuals is further compounded by various cross-demographic issues. These can be affected by age, cultural background, socio-economic factors, level of education, past media habits, and a myriad of other factors (Reinecke and Gajos 2014). While our specific case centers around differences in preference and recognition in visual communication between teenagers in Nepal and Sweden, similar issues can be encountered when working with two distinctly different age groups in the same region. This is yet another reason we want to present

development guidelines that can aid developers in creating clear and appealing visual communication regardless of which demographic issue they might be facing.

4.1 Choosing Which Objects to Depict

A common mistake among developers and artists alike is that their design decisions - unbeknownst to themselves - are heavily informed by personal biases. If you ask two different people to draw a picture of a computer, one might draw a laptop, while the other might draw a desktop computer. This is going to be informed by many factors, such as their own lived experiences and what types of computers they commonly encounter, their personal media habits, cultural context, interests, level of education, and age. When making a serious game about cars, then, what type of car should we use to effectively communicate with our players? Or, in our case, which food item should we use while considering the factors of personal media habits, interests, cultural context, etc. in Nepal?

Here we have found it useful to use Rosch et al. (1976) concept of taxonomic hierarchies of objects. According to Rosch et al., people recognize objects at different levels of specificity - the *superordinate*, *basic level*, and *subordinate.* Building on Rosch et al., Lakoff (2008) concludes that: "The fact that knowledge is mainly organized at the basic level is determined in the following way: When subjects are asked to list attributes of categories, they list very few attributes of category members at the super-ordinate level (furniture, vehicle, mammal); the list most of what they know at the basic level (chair, car, dog); and at the subordinate level (rocking chair, sports car, retriever) there is virtually no increase in knowledge over the basic level."

To give a brief introduction of the concept, these levels can be understood as: superordinate = animal (the universal level), basic level = horse (a more specific category of animal, but still broad), and subordinate level = Shetland pony (a very specific subcategory of horse). This can also become increasingly complex, with subordinates within subordinates. For the purposes of our work, and for general serious game development, we have translated the hierarchies of superordinate, basic level, and subordinate into a spectrum ranging from '*universal'* and '*specific'* (shown in Figure 2).

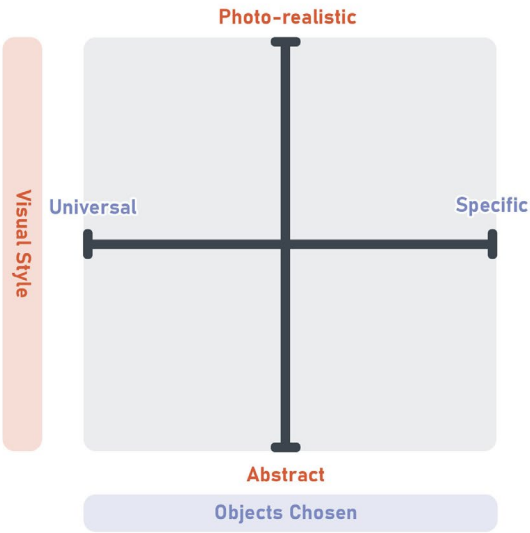

Figure 2: We have developed a model to strike a balance between clarity and appeal in serious game visuals. The model is represented by an X-axis spectrum ranging from universal to specific and a Y-axis spectrum ranging from photo-realistic style to abstract style

We have tied this model to our own project (shown in Figure 3). The first category comprised of 'Specific' Nepalese food items like roti (a type of flat bread), barfi, and samosa, which were selected to elicit a sense of daily familiarity. However, in a different cultural context, these items may need to be substituted with other appropriate options. The second category included 'Universal' food items that have a universal visual representation, such as fruits (apple, mango), vegetables (broccoli, pumpkin), and meat. The third category consisted of food concepts that have different visual representations in various cultures and may lean more towards either the 'Universal' or 'Specific' category.

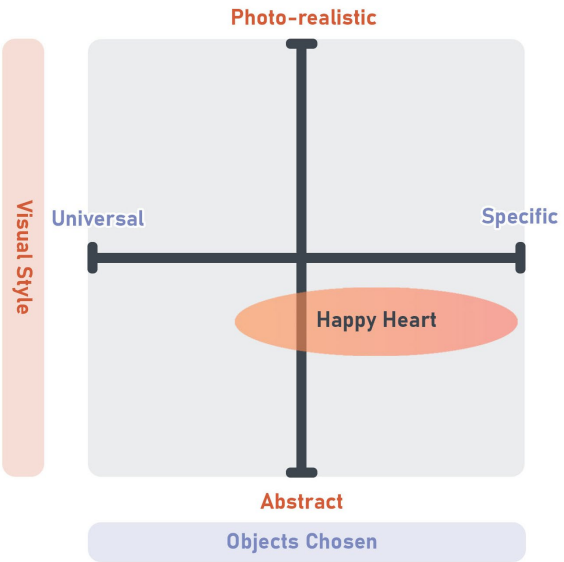

Figure 3: The range we have chosen for our serious game Happy Heart is denoted by a red oval on the model

The most complex aspect of compromise lies in the third category, illustrated by the example of beer. Beer as a general concept can be a very broadly recognizable visual representation, while in Nepalese culture it has a different type of look. There are three aspects of concern when we make compromises. First, as we found in earlier studies conducted in this project, localizing serious game images should take players' pre-existing visual experiences into account (Bai, Berg Marklund and Zhang, 2022). Participants in this previous exploratory study preferred familiar images from games. Therefore, a more universal representation might be better suited for the games they typically play. Second, based on Biederman's (1995) research that "Most of our knowledge of the visual world can be accessed through the basic level", specifying the subordinate-level class—for example, that something is European brand beer versus Nepalese type of beer—provides only a slight increase in informativeness at an enormous loss of distinctiveness. That is, the difference between the two types of specified beer is much smaller. While a specific type of beer bottle is prevalent in Nepal, an image of a beer glass filled with beer might be more quickly recognizable. From a learning perspective, it might not be detrimental to acquire knowledge by utilizing either. Additionally, the visual representation of this issue would also be of concern. We should notice that beer is one of the basic objects presenting a superordinate level of "alcohol" to discard into a trash bin in the game. The target group has low knowledge of alcohol-related health problems according to the KAP study. As a result, we depicted beer falls under the 'Universal' category based on our analysis.

An example of selecting more specific items to be depicted in the game is roti. In the exploratory study in Nepal, we found that participants could easily recognize almost all "natural" food items (unprocessed food). It was, however, difficult for participants in the test to recognize many cooked food items (Bai, Berg Marklund and Zhang, 2022). For example, the cooking methods for a roti can include folding, flattening, inflating, or filling it with other ingredients. Recognition might very well be tied to how similar it is to how the participants are accustomed to eating the specific food. Based on this, we took more care to select the appropriate shape of local food items.

When considering other visual elements in the game, such as background design and interaction elements, we encountered a dilemma in making a choice. During a field study in Nepal conducted by members of the game development team, we found that steel-made tableware is common in the kitchen. Therefore, we chose steel plates as part of the interaction element in the level Master Chef whereas we identified contrast issues. When players move the food elements on the plate, the graphics could not provide a solid contrast between the plate and the food items due to the overall color scheme. The lack of contrast made it difficult for players to properly make the right decision in the game and navigate the screen. Value (Brightness) between objects is too close. According to Norman (2013), people can understand how things work based on their visible structure, such as affordances, constraints, and mappings. Although participants may have never seen or used other types of plates, they could recognize that the number of possible actions were limited. As a solution, the game graphic team replaced the steel plate (gray) with a regular porcelain (white) plate in this case.

4.2 Choosing the Visual Style

Once appropriate objects have been identified and categorized according to the purpose of the serious game, it is then important to choose the level of stylization that best suits the players' preferences while still maintaining clarity and making objects easy to identify with a minimal risk of misinterpretation. This is where the correct balance between clarity and appeal needs to be found.

It is important to note that this decision should not be taken lightly, and a developer needs to be fully aware of the compromises they're making when choosing their visual style. We suggest that the primary factors guiding this decision are: audience characteristics (e.g., age, level of education, cultural background, media habits, etc.), end-users' hardware, the game's purpose and area of application, development budget, and the development team's skillset. Take our project as an example, we began with a literature review that indicates realism and too much detail might be counterproductive in the serious game (Bai et al., 2022). Considering our target platform as Android smartphones, we were also aware of the constraints it imposes on graphical design. Thus we framed the graphic style into an abstract style. The exploratory study in Nepal tested the recognition and preference of different levels of fidelity among the target group. The results suggested using the abstract style with color and hard shading, without the outline.

Returning to the "beer" example, even the 'basic level' we chose for its shape (a glass with yellow-ish liquid with foam on top) can still be drawn in different styles. It could be a high-polygon count, photorealistic glass of beer with simulated liquid physics, or it could be a stylized or highly abstracted style. For the context of Happy Heart - given its audience, purpose, end-users' hardware, and the development budget, a cartoon style was deemed the most appropriate. A more abstract visualization could lead to a lack of both clarity and appeal. The beer might, for example, be confused for a soft drink - and the higher level of abstraction would also be unsuitable for the target audience's visual preferences. And while an even more realistic style may have been more appealing (for example a 3D object with more detailed textures), the level we chose provided the optimal balance of appeal and clarity according to the audience, budget, hardware, and purpose factors of our project.

5. Outcomes and Results

What we consider to be innovative is, however, the development process and the examination of factors that inform the way a game should look and function to be successful in different use contexts. From a broader theoretical perspective, the innovation resulting from our work is a methodology that can improve decision-making in development processes. This methodology comes down to tackling two particular dilemmas: choosing between established taxonomic hierarchies for what you're representing in your game, and choosing between realism and abstraction for how to represent it.

We, in particular, hope that the model helps developers make more efficient choices while still making an appealing game that achieves its purpose. Establishing the right level of object representation (i.e., which level in the taxonomic hierarchy is necessary), and the necessary level of fidelity (in the continuum of realism and abstraction), will help a team find the right compromises fitting their games' purpose. This does not just have to be limited to specificities found in geographic regions - the universal-specific spectrum can also apply to subject matter details. If you are making a game about car repair for an 18-year old who got their first car, depicting basic level objects like engine, battery, and the fuel tank in a stylized way might be sufficient. If you're making a game about car repair for a mechanic, you need to dive deep into the subordinate level representations and clearly represent a 2.0-liter hybrid inline-four gasoline engine, and clearly make the car parts visually identifiable (e.g., belonging to specific car manufacturers). Making misinformed choices about what graphics to use for either case can, at best, lead to an unnecessarily inflated budget, at worst, lead to the player learning the wrong things or a fundamentally unappealing game.

It is important to note that we would not have been able to make these choices for Happy Heart, and understood the problems with our original assumptions about what type of graphics our game would benefit from, if it wasn't for our access to a research team in Nepal. Without that team, we would not know where a 'subordinate' (i.e., specific) object was necessary, and where a 'basic level' (i.e., more universal) object was sufficient. With access to insights into Nepalese teenagers' reference frameworks, we could find the compromises that made our development cheaper and more efficient, while still communicating valuable information and decreasing risks of misinterpretations of the subject matter. In our own research examining the preferences the target audience has in terms of the game's visual style, we were also able to identify which level of stylization hit the right compromise of being appealing and clear. Knowing that a cartoony style hit a

good balance between clarity and appeal, we could then be sure we didn't "waste effort" in pursuing a higher degree of realism in our game objects than was necessary.

6. Conclusion

While all game-based learning solutions are complex and need significant deliberation and communication between stakeholders to be successful, creating even mechanically "rudimentary" game-based learning solutions become even more complex when they are intended to be used in cultural settings outside of the developers' lived experiences.

A serious game's graphics should not be decided upon haphazardly. It should not just be thought of as a facilitator to a serious game's gameplay, it needs to be understood as a fundamental pillar that supports the game in achieving its ultimate goals. With a better understanding of when different game visuals are more or less appropriate, both in terms of style and in which objects are represented, game developers will both be able to balance production costs better while also creating something that strikes the compromise between clarity and appeal.

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Informal Game Play in the Classroom: Utilisation and Integration of the Metalanguage of Games

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Abstract: This paper discusses a case study of a 28 children in a middle years (11-15 year old) classroom and the use of the "third space" between the classroom and the home as an area of play for consolidation of both the learning at school and the informal learning of the games played at home. The research aims to look at whether the third space could be a vehicle to enable participants who have identified themselves as competent in the gaming world to link those learning strategies to classroom learning and therefore transfer that success to the classroom. The research took place at an International Baccalaureate school in Perth, Western Australia and utilises the third space as a gaming server and Discord chatrooms. Data was collected from the servers, questionnaires, researcher observations, game walkthrough videos and through interviews with the participants. Being an International Baccalaureate school the children take part in a "cognitive curriculum" which is part of the metacognitive learning of the International Baccalaureate. The participants were applying these strategies to their reflections on their action within the server and these reflections then informed their further participation within the "informal" game. In this way it could be theorised that children who were skilled "shapeshifters" could be at an advantage both communicating within the collaborative group work and moving between the informal and formal spaces. The analysis of the data focuses on the ways in which the students unpacked, utilised and discussed the formal classroom learning whilst participating in the Java Minecraft server game space. The metalanguage of learning and building competence in digital games informally through play outside of the school appears to link well to the metalanguage of the International Baccalaureate curriculum. The paper investigates whether linking children's understanding and use of the gaming metalanguage to the International Baccalaureate metalanguage enables children to traverse the metalanguage of the classroom more successfully. The analysis of the data is utilised threefold in this presentation to: Identify that there is a linkage between gaming language and International Baccalaureate curriculum elements make these links apparent and show how they would apply in the classroom.

Keywords: Third space, School, Middle Years Education, International Baccalaureate, metalanguage, Minecraft

1. Introduction

This article examines informal learning in a third space offered by a Minecraft server that formed the basis of an after-school club. The Minecraft environment was built for use outside of the school setting and much of the activity happened on the server in out of school hours. The study takes place at an International Baccalaureate (IB)Middle School and looks at the children's engagement with Minecraft as a site of informal learning. The research upon which this article is based was conducted between July and December 2020. The qualitative data collected included interviews, focus group discussions walkthroughs of game plays and house builds and video footage. This was analysed through themes developed in NVIVO.

Online games are areas middle school students have power and agency. Understanding the mechanics of participation and the metalanguage allows students to participate in global meeting and creation places that most teachers fear to go. Through a socio-material framework playing Minecraft can be understood as actual building and creating in a third space, not merely a representation of building (Dezuanni, 2016). This research study looks at the use of an authentic gaming space to develop student agency whilst applying the OECD (The Organisation for Economic Co-operation and Development) Sustainable Development Goals (2018) and Goal 2 of the Alice Springs (Mparntwe) Education Declaration (2019) of resilience and problem solving.

2. Third Space as an extension of the classroom

The third space is a concept in cultural theory developed by Bhabha (2004) and has been appropriated and used in the education sphere often in conjunction with looking at the performative aspects of digital literacies education and online play (Guitterez, 2008; Dezuanni, 2016, Impedovo and Cederqvist, 2023). Potter and McDougall (2017) argue that it is rare that a third space within school grounds could ever subvert the structures of authority that is described by Bhabha in his initial definition of a third space. This assertion explains why this type of research and the use of *Minecraft* in conjunction with the Essential Elements of the International Baccalaureate are important. *Minecraft* allows a space for the subversion to occur as the authority figures are not powerful within it and the students hold all the power through their knowledge of the game. However, the reflections through the language of the International Baccalaureate (IB) allow the researcher and educators to understand how the participants are thinking and learning within the server through utilising the metalanguage of the IB for students to explain their participation and gameplay.

In the broader contexts of everyday life, contemporary media practices and sociality, *third places* are understood as 'meeting places' or 'hangouts' that sit outside the domestic environment (first place) and institutional domains such as school and work (second places) (Oldenburg, 2000). They are typically neutral ground characterised by belonging, togetherness, accessibility, and playful interaction. In game studies and social media scholarship, the concept of the third place has been appropriated to signify the way online multiplayer games and social media platforms constitute virtual meeting places or digitally mediated community gathering sites (Steinkuehler et al, 2006; Ducheneaut et al, 2007; McArthur and White. 2016). Games are now understood as important and established third places where people meet, nurture long-lasting friendships, and form persistent communities. Playing and talking together through games, especially during times of enforced physical separation such as that experienced during the Covid-19 pandemic, fosters and maintains deep connections across generations and cultures. *Minecraft* is a particularly robust and lively example of such practices (Hjorth et al., 2020).

This research both tapped into and fostered the creation of a third space that subverted the normal power bases of the school. *Minecraft*, an informal gaming world similar to those children play in out of school for leisure, is a persistent third space removed from the classroom or other societal powerbase (Callaghan, 2016). However, there is a need to build the discussion on the autonomy and agency of players as they constantly change, build and create a constantly evolving world. This is important as, in this third space, participants face a completely different set of norms, rituals and values to the outside world. The different set of norms allow the students to be the primary agents within the game which means they also have power over what they choose to learn, who they want to interact with and how they are going to develop the game play. In this co-constructed world, participants play with new concepts, ideas and game play strategies, generally without fear of approval or disapproval.

Schools have been criticised for the way in which they are not linked to the outside world which they prepare their students to enter (Zhao, 2020). This difficulty was encountered in the research process, when setting up an online space that was not within the formal school setting. This research was approved by five schools' administrations and technology departments to be run in their schools. However due to school system firewalls and system wide blockages it was difficult to enable the Minecraft java server to be accessed in these school technology systems. Even with full school administration permission and a game that posed no risk to the schools or the students the firewalls could not be altered to allow the game to run in most schools. Of five schools approached in Western Australia, this International Baccalaureate school site was the only school that met the study's selection criterion of bringing the outside world into a third space within the school by adjusting their security protocols.

The decision was made to implement *Minecraft* Java Edition on a private server rather than the schools' *Minecraft Education Edition* as it gave student participants more agency through their actions and designs and access to the latest upgrades through mods (modifications and add-ons) made by the global community of *Minecraft* players. The student participants had power to change and create their identity and the Minecraft world they played in. They were able to re-design the standard template block figure (also known as Steve) to reflect how they wanted to be represented in *Minecraft*. This fits very strongly with Bhabah's (2004) notion of the performative nature of identities where people are continually able to remake boundaries and renegotiate their own image put out to the world and where they are now, and how they may look.

3. Discussion of the student's utilisation of the third space in the game

This option of being able to change skins, identities and essentially virtually "shapeshift" allows children in third spaces to be able to trial new ideas and strategies with the option of the worst case scenario being that they need to shapeshift to a new identity if they lose everything. This allows children room for productive failure, ref needed but it also gives room for children to escape reality- sometimes with friends from their "real" world. Online games are spaces that research has demonstrated middle school students have power and agency over their identity, play and participation. Understanding the mechanics of participation and the metalanguage allows students to participate in these global meeting, play and creation places that most teachers fear to go. Through a socio-material framework playing Minecraft can be understood as actual building and creating in a third space, not merely a representation of building (Dezuanni, 2016).

There were data collection points throughout the research where the participants discussed reasons why they wanted to play within the server and take part in this research. They also discussed the background of how they had become involved in playing Minecraft out of school as part of their initial onboarding questionnaire and in the initial focus group meetings. These stories were very insightful and gave a look into the why these spaces

are important for middle school children to be able to participate within as they are going through the shifting identity development of their early teen years. One of the children within the study discussed how they had created a creative world in Minecraft that they shared with a friend who was in the same split family situation as them. Essentially, they were moving between two very disrupted families from mother's house to father's house. They would take their Tablet device with them and play in the server at both homes. This server world was their stable world where they had control over the what the created, strategies they implemented and communications with their friends. They had divided the world into two halves- one yellow (the friend's side) and theirs was blue. They played together here and had developed a combined "zoo" where they kept a few of all the different creatures they had found in Minecraft. Online games are areas middle school students have power and agency (Dezuanni, 2020). They saw themselves as explorers of the realm

> *Bill: "I am an explorer and as with all explorers all through history things go wrong- you learn to deal with it—you don't get to do this in the real world anymore- everything and everywhere I can go has already been discovered."*

The two children worked on the exploration and development of their Minecraft realm together. They were constantly problem solving in this realm to be able to keep all the animals in their zoo alive as well as searching for ways to make all objects in each side either yellow or blue. The children all agreed that understanding the mechanics of participation and the metalanguage allows them to participate in global meeting and creation places:

"*It's that we all share something in common that we can talk about and inspire each other to do things. It's a bit of a break from the real world.*" With one of the most attractive aspects of participation being that most teachers and parents fear to go to these places, so the children are allowed to participate freely in this space. This was was a topic of discussion about both Minecraft and the Discord messaging system that was used.

4. Lessons from the Server: What can we learn from this to bring into the classroom?

Benwell and Stokoe (2013) discuss the importance of space in a post-modern, Foucauldian sense impacting the development of identities more than place. This is reflected throughout this research. It was important that the space provided had the significance to the participants and would enable participation as though they were in a "cool" external space. One that resembled the home and world of popular Minecrafters as it was only through providing this type of space we could invoke the identities the participants have and have developed in these spaces (informal), rather than the identities they possess in the school (formal) place. Spaces build identities rather that identities building spaces (Benwell & Stokoe, 2013) In this case, this is significant as the Minecraft Education world puts limitations on participants whereas the original Minecraft game opens the possibilities of boundaries, powers and objects that are not available in the school space.

The java server Minecraft world was developed as a place that provided an informal enabling space where participants would feel that their "Minecrafter" identity was valued and where they had agency to utilize all their skills and knowledge from "outside" participation within Minecraft. However, the Minecraft club was located within the "Place" of the school classroom. The school classroom invokes a different identity – a more formal "school" identity and with this the more formal school processes and organization and time frame. Benwell and Stokoe (2013, p.278) discuss the importance of the individual establishing the appropriate identity for the space and interacting discursively with others to build this identity During the club, there were multiple intersecting points between the formal classroom and informal third space. The participants could be drawing from the discourse of the two identities, formal and informal, at different points of the session, identifying the appropriate times to move or "shapeshift" from one identity to another. Participating in the discourse appropriately is a skill participants developed through the study. In their reflections in the formal school space about their participation in Minecraft, they interpreted, reflected and analysed their actions in the language and discourse of the International Baccalaureate. There are many cognitive thinking strategies which are part of the metacognitive learning of the International Baccalaureate and along with these there is the metalanguage to explain them. One of the key artefacts collected by the researcher in this fieldwork were narrated play and creative house build video walkthroughs. These involved the participant recording their play and then putting the recorded narrative over the top of it to reflect on and explain the gameplay that was occurring or to give a house/world walkthrough of their creation in Minecraft so that the researcher could understand the build and all the elements that had been utilized to create the special features of the building. During this the participants were applying this metalanguage of the International Baccalaureate to their reflections on their actions within Minecraft so that both the researcher and the teacher in the classroom could understand their walkthrough

videos. The walkthrough videos then also gave the students a space to reflect these reflections then informed their further participation within the ‘‘informal“ server space. In this way the metalanguage of the International Baccalaureate was translated and utilized to improve the Minecraft play.

5. How Can These Findings Be Applied to the Classroom?

Metalanguage is taught to children in Australian classrooms as part of Literacy (ACARA nd). It is a fundamental aspect of analysing multimodal texts in a way that allows the students to systematically analyse and explain conventions authors have used in their choices of design or language to create or amplify meaning (Kress and Van Leeuwen, 2006; Lim, Cope and Kalantzis, 2022). There is also a metalanguage that is part of the reflective nature of the curriculum within the International Baccalaureate (IBO, nd). These are terms that are used to explain the learning through the attitudes and metacognitive skills that students utilize as part of their learning. Students apply this metalanguage in their goal setting and reflections on learning as part of the Inquiry programme of IB schools. When children participate in games and communicate between one another in games they are constantly analysing and reflecting and reviewing theirs’ and others’ game play- this can be seen with the popularity of YouTubers who dissect their own game play (Taylor, 2018). These Youtubers and children understand a common metalanguage for breaking down and discussing the games, builds and theirs and others gameplay. To make these accessible for the classroom to use educationally it is important that this metalanguage can be translated for teachers and a “Newbie” audience. Translating the metalanguage to a school audience is a skill in translation which the participants in this research demonstrated increasing mastery in through the duration of the study.

6. Data Analysis and Metalanguage of Games Findings

Game design and game play within the design is a specific language of its own (Harrer, 2018). Games are a multimodal combination of sound, narratives, imagery, gameplay, puzzles and backgrounds/scenes that communicate an idea or experience to a player through multiple layers of sub-text. Understanding the metalanguage of games is necessary to be able to analyse games, just as knowing metalanguage is for sports or art compositions is necessary to be able to analyse and discuss their merits. Disciplinary literacy – or understanding of the underlying metalanguage is a challenge for all learners regardless of their cultural and linguistic background. Teachers in each of the disciplines should be involved in talking about language and meaning through meta-language in their classroom (Humphrey, 2017). Participants in the study were able to bring their expertise in the game of Minecraft and the literacy involved around participation in the game to share and explain to an audience that did not have the expertise in the metalanguage of the game. They then understood that this needs to be translated to the metalanguage of the classroom to be understood. This translation of the metalanguage allowed the participants to see that their expertise in the game is valuable in formal school spaces as well. The translation also allowed the participants to use another set of analytical tools to reflect and further develop their creative builds or play. The walkthroughs used as part of this research work as a personal exploration of how the game that they have played or create, expressed their themes and purposes through the use of common game techniques from Minecraft.

The videos were analysed in NVIVO and in looking at the metalanguage of gaming used the researcher analysed the videos through the main areas of the:

- ***Isolated Meaning of Features of the Game*** Discussion (Music, colour palette, style, narrative of the play etc)
- ***Associative Meaning of Features in the Game*** Discussion (Feel of different elements of the gameplay where different elements are combined)
- ***Dynamic Meaning of the Features*** of the Game discussion (where new meanings and emotions are created or where the player has researched or created outside of the game to enable further participation).

These categories were taken from Floyd and Portnow’s (2017) Metalanguage of Game Design and were found to apply well to the discussions children had about their play in Minecraft. As can be seen in this very brief snapshot of the data this participant is very knowledgeable and able to express themself in this metalanguage discussion of Minecraft at all three levels.

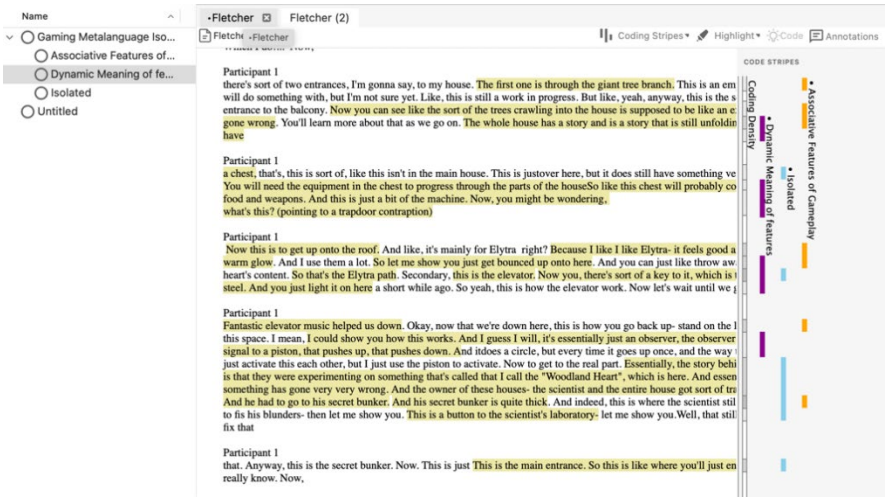

Figure 1: Transcript of Game Walkthrough Video coded for Game Design Metalanguage

What is interesting is if we then look at the comparison of the use of the Metalanguage of the International Baccalaureate within the same video to explain the Minecraft Creative build to the researcher.

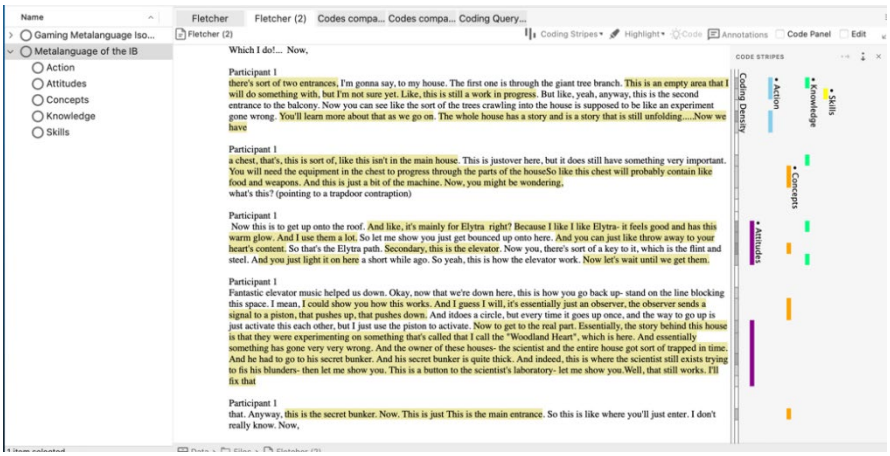

Figure 2: Transcript of Game Walkthrough Video coded for International Baccalaureate Metalanguage

The participant knowing the audience they have produced this for, has used the elements of the metalanguage of the formal IB classroom to be able to explain it – and without realising demonstrated how this can be viewed from a "formal learning" perspective. Metalanguage use within games was one of the categories of demonstrating advanced Gaming literacy (Apperley and Walsh, 2012). Gaming literacy per se is not one of the outcomes of the International Baccalaureate curriculum however meta-cognition, attitudes and learner attributes are. The participant has aligned these in his description of his activity within the game in order to allow the researcher to see the inherent value within his gameplay.

7. Conclusion

On the last day of the fieldwork after the participants completed their final reflection, the teacher who had been assigned by the school to work within the project commented: "*thank you for advocating for our children*". This was significant as the classroom teacher could see that through researching popular gameplay from the children's perspective adults can view the online play from the perspective that the participants see it. The teacher also discussed that the idea of Productive Failure being inherent to learning within the game and that being reflected in the attitudes to playing by the children enabled a lot of the anxiety of trying new ideas to dissipate. She commented in her reflection that: '*seeing these children try without fear of failure is very much apparent within the game and it is good to see students in the group who are often not engaged interacting and laughing but trying again when things went wrong in the game*.'

Student agency for 2030 is rooted in the belief that students have the ability and the will to influence, positively, their own lives and the world around them. Student agency is defined as the capacity to set a goal, reflect and act responsibly to effect change (OECD 2030 Map, 2018). The International Baccalaureate focuses on a

curriculum that prepares students for the 21st Century through a Cognitive Curriculum that explicitly teachers the metalanguage of metacognition. This teaches students how to set goals, map a plan to achievement of goals and then reflect and is line with the OECD 2030 map. This terminology can assist children in utilising the metalanguage of digital games, such as Minecraft, to be able to translate this into terms that are understood within the formal classroom. Thus, allowing students to be able to communicate their depth of knowledge in games as well as display their digital literacy skills. The research indicates that Multi-Modal literacies are ever expanding and understanding the metalanguage of games could become an important skill as we head towards 2030.

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Designing a 3D Serious Game About Career Pathways in the Games Industry

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Abstract: The aim of this paper is to give a detailed overview of the development of a 3D serious game that informs game students about career pathways in the games industry. The paper provides a scoping review on the key principles related to serious game design. These core design issues are reiterated in relation to how the development of the game has adhered to them. The paper illustrates the game's audit trail in terms of implementation providing a development blueprint for other educators to follow when developing an educational game. The learning outcomes of the game are also accentuated and how the implementation of the game has catered for them. An important aspect of the paper is to highlight how the underlying aspects of game design can accommodate intrinsic content and motivation whilst accommodating the various pedagogical frameworks embedded in the gameplay. The characterising goals of the game have adopted a linear and cyclical approach that allows the player to progress through the gameplay completing formative and summative assessment challenges. The serious game was developed using the Unity game engine adopting a hub and spoke design. A key challenge when designing the game was how to ensure that the game remained endogenous when designing the game's levels. The design considerations presented in this paper provide a solid implementational framework about how to implement principles of learning and assessment associated with employability skill sets with a specific focus to the games industry.

Keywords: Serious games, Games industry, Graduate skill sets, Employability, Career pathways

1. Introduction

There appears to be no unanimous definition of what constitutes a serious game. Serious games can be defined in the way they have been developed and also how they are to be played (Dörner et al., 2016). Furthermore, the categorising of games and their intended aims and objectives from a gameplay perspective can be achieved in relation to their primary purpose. For example, according to Connolly et al. (2012), when classifying a game, it is beneficial to reflect upon the precise purpose of the game. For example, many of today's AAA game industry releases are predominantly developed for a player's enjoyment, to have fun and accommodate recreation. By way of contrast, games-based learning and serious games are more predominately related to learning and behavioural change. Various definitions of serious games exist in the academic literature. Dörner et al., (2016, p.3), define serious games as "…a digital game created with the intention to entertain and to achieve at least one additional goal (e.g., learning or health). These additional goals are named characterizing goals". Whilst this definition does imply that serious games have to provide an element of entertainment for the player they should be designed with an additional purpose. A common design component of serious games is the aspect of learning or more specifically the learning outcomes of the game. Van der Linden and van Joolingen (2019, p.16) state that "A serious game is a computer game with the aim of facilitating learning in addition to entertaining users". This definition coincides with the one proposed by Dörner et al., (2016). Ravyse et al., (2017, p. 32), the primary challenge of a serious game is to *"… find a balance between the ludic and skills or knowledge transfer goals so that neither a dominant game mode nor learning mode is present".* This definition summarises one of the main challenges when developing a serious game, namely, which relates to the aspect of game balance. This definition relates to one of the salient principles of game design, namely that in order for the game to be fun, there must be a degree of choice and self-determination for a player to make progress within a game. One of the main challenges when conceptualising an idea for an educational serious game is determining what the role of the educator is within the serous game design and development (SGDD) process (Dimitriadou et al., 2021). This paper provides a case study on the development of a 3D serious game to teach game development students about career pathways in the games industry. At present, the paper does not provide any empirical results but is intended to give an overview of the SGDD process and the justification of the decisions made towards the game's development. In addition, the paper provides a reflective account in relation to the role of the educator in the design process, the impact of creativity regarding the design team and future recommendations.

2. Serious Games Design Models and Frameworks

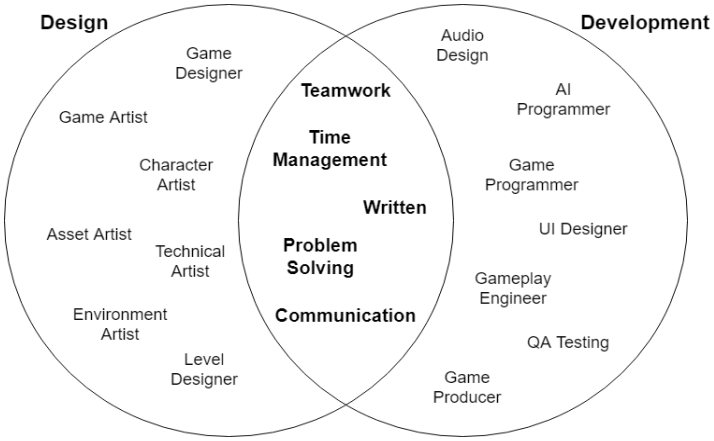
It has been argued in the academic literature that there is not an overall uninform approach for developing games for educational purposes (De Freitas and Oliver, 2006). For example, according to Westera et al., (2008), some frameworks focus predominately on the technical aspect of the development as opposed to combining this with the educational elements associated with the design. For example, several game design frameworks exist in the literature such as Schell's (2020), "elemental tetrad" which focuses on the components of technology, aesthetics, story, and game mechanics. The game mechanics relate to the mains aims and objectives of the game and the boundaries of the game in terms of what the player can and cannot do. In this framework, it is important that the technology you utilise can support the mechanics, aesthetics that illustrate them to the player and a story the materialises in accordance with the game mechanics of the game. The Mechanics, Dynamics, and Aesthetics (MDA) framework proposed by Hunicke, LeBlanc and Zubek (2004) provides a differing perspective on how a designer and a player view a game. Players of a game have a tendency to focus on the game's aesthetics whilst designers predominately focus on the mechanics of the game. It is advocated that when considering the components of games, it is useful to reflect upon both designer and player perspectives. One of the challenges when developing a serious game is how best to underpin the game with pedagogical theory that are associated with its learning outcomes. Some educational game design models have advocated ways to achieve this such as the experiential gaming model (Kiili, 2005). The aim of this model is to bridge the gap between educational theory and game design with flow theory adding to the overall immersion and player experience of the game. Ibrahim and Jaafar (2009), have presented an educational games design framework. The model blends together game design, pedagogy, and content modelling though at the time of writing, has not been empirically evaluated. The primary aim of the model is to provide an effective design methodology and guidelines for development teams when creating educational games. Mitgutsch and Alvarado (2012), developed a Serious Game Design Assessment Framework (SGDA). The framework stresses the importance of reflecting upon the purpose of the game when undertaking its conceptual design process. The focus of the aim, purpose and impact of the game is central to this framework.

3. Serious Games and Pedagogy

A primary aim of serious games is to ensure that the learning goals of the game are underpinned by the appropriate pedagogical theories for the player to achieve these goals. Learning outcomes for a serious game could be cognitive, skill-based, or affective (Braad, Žavcer and Sandovar, 2016). Benjamin Bloom's taxonomy (1956) is sometimes often affiliated with pedagogical considerations when designing serious games. For example, the cognitive domain of the framework focuses on knowledge construction, the understanding and application of that knowledge, analysing, synthesising, and evaluating it. The application of the cognitive domain, it can be argued, is applicable to the foundations of the learning goals of most serious games. Dependent on the genre of the serious game, problem-based learning (PBL) is a pedagogical approach that facilitates critical thinking and student-centred learning towards solving realistic challenges and problems. For this to be supported in the context of instructional design, and for learning to take place, the learner has to be firstly motivated to learn. For example, self-determination theory, as conceptualised by Deci and Ryan (1985), posits that intrinsic motivation occurs when you do something because it is inherently interesting or enjoyable. It is predominately associated with cognitive and social development. In contrast, extrinsic motivation relates to undertaking an activity because it is associated with an ulterior motive such as obtaining an external reward of some kind.

4. Games Industry, Employability and Serious Games

The games industry comprises a diversity of job roles in the context of games design and development. These are exemplified in figure 1. A challenge educators face is how best to educate and inform game development undergraduates about the necessary career pathways and skill sets required to work in the industry (Baxter et al., 2022). It is the view of the authors that the development and use of a serious game has the potential to address the 'knowledge gap' in educating game development students on the diversity of career paths within their chosen industry.



Adapted from CG Spectrum, Game Development Careers (2022). Available at: https://www.cgspectrum.com/career-pathways/game-development

Figure 1: Soft and hard skills required in the games industry

5. Design of a Serious Game to Teach About Skill Sets for Games Industry

5.1 Thinking and Logic Behind Game Design

Serious games and digital games played for entertainment developed in the AAA games industry both adhere to certain game design concepts such as gameplay and mechanics. However, serious games are often designed to educate individuals on subject areas such as health and safety awareness to enhance the user's knowledge and understanding of the subject. The aspect of pedagogical content integration and how to achieve this was an important consideration regarding the game's development. It was decided that in relation to the game mechanics, that as opposed to the utilisation of extrinsic content, that the learning content would be integrated within the framework of the game. The embedding of intrinsic content would ensure that learning and gameplay would be closely related to one another and happen simultaneously. It was also important that the design ideas and logical underpinnings of the serious game would therefore accommodate the pedagogical theories underpinning the learning content of the game.

The original design plan for the serious game proposed a sole game studio environment, with subsequent modifications aimed at enhancing a varied gameplay experience for the player through the incorporation of game and level design techniques and typologies. The key factor in the game design was to accommodate the concept of an endogenous educational game where the game play is informed by the learning content and pedagogical theory. Students will be assessed in various 3D environments with the primary outcomes of obtaining information and thereby solidifying their knowledge about job roles and career pathways in the games industry. An additional output of the serious game is to guide and support game development undergraduate students in their career pathway choices and to help them gain a greater understanding of how job roles interrelate in the games industry. From a game design perspective, it was crucial to design and develop a game that would resonate with the students, gaining inspiration from focusing on genre-specific mechanics that game development students could relate to. The serious game integrated a well-established level design typology known as "hub-and-spoke". This typology features a central hub serving as a safe place for the player, with multiple branching locations to various areas (The Level Design Book, n.d.). The central hub symbolises the initial game studio environment from original design plans for the game. Each level or branch is dedicated to a specific job role within the games industry, such as design, programming, art, animation, and quality assurance (see Figure 4). To create diverse experiences for the player, each level focusses on an individual job role and game genre thereby adding an element of fun and engagement for the player. Whilst embedding an element of fun into the game, the levels facilitate a sense of exploration for the player with a degree of linearity for the content. The levels including art and animation were merged, due to the similar nature their job roles thereby allowing for more extensive game play in terms of player navigation and exploration (see figure 2). It is important to note that [1] and [5] are currently in development at the time of writing this paper. Figure 3 details original simplified design plans of the [2], [3], and [4] from Figure 2.

	Level	Game Genre	Typology
1	Game Studio	Sandbox	HUB
2	Design	Platformer	Branch
3	Programming	Puzzle	Branch
4	Art & Animation	Role-Playing Game (RPG)	Branch
5	Quality Assurance (QA)	First-Person Shooter (FPS)	Branch

Figure 2: Serious game level design genre typologies

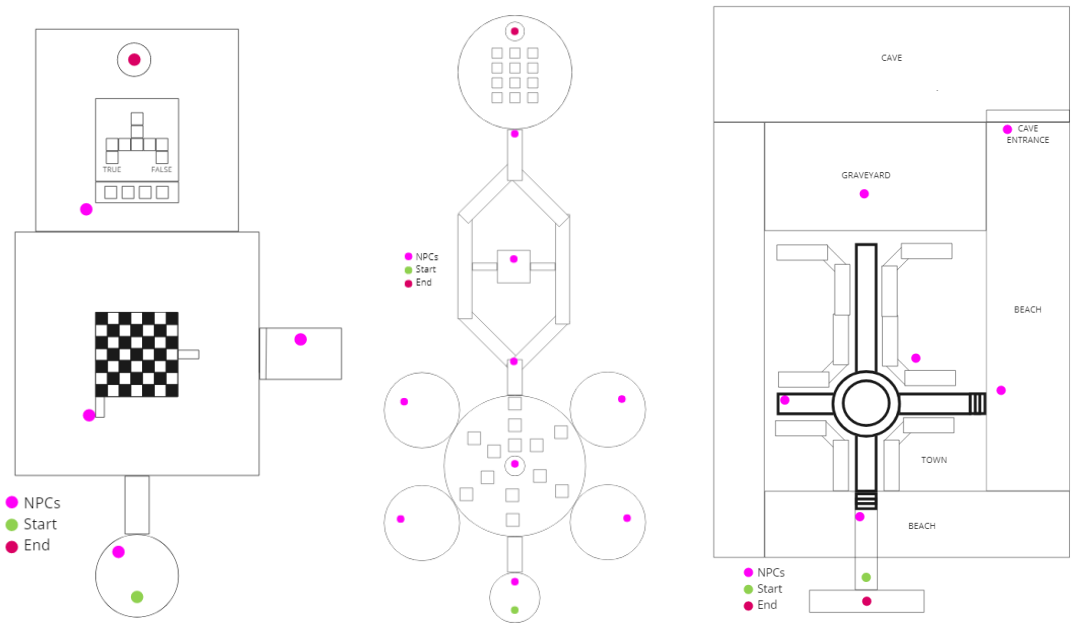


Figure 3: Design, programming and art and animation initial level top-down layouts

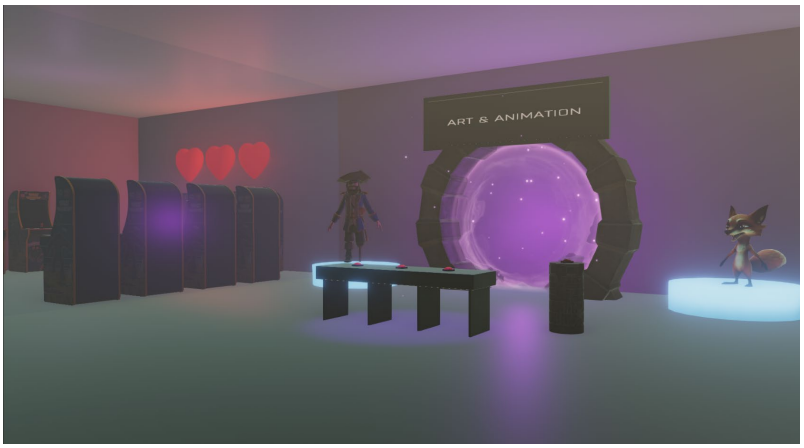


Figure 4: HUB guiding player to the art and animation level (work in progress).

Development Environment and Content Creation

The popular cross-platform game engine Unity by Unity Technologies (n.d.) was used for the core development of the serious game and was assisted by the Unity Asset Store for time-intensive resources. Some game resources were created additionally using Maya (Autodesk, n.d.), ZBrush (Pixologic, n.d.), Substance 3D Painter (Adobe, n.d.), and Photoshop (Adobe, n.d.). Unity was the core engine used by the developers to create the serious game. Justifications for using Unity were its versatility in supporting the development of both 2D and 3D games. It was also considered that in relation to future developments of the game, Unity has the ability to

support gameplay across game devices and platforms (e.g., iOS, Android, PC) and supports mobile game development.

Content Integration Through Game Mechanics

The primary goal in the game design process was to establish a universal game mechanic that integrated content within the serious game. To achieve this aim, a dialogue system was implemented as a core mechanic across all levels of the game, enabling players to engage with non-playable characters (NPCs). The design of this dialogue system was inspired by the RPG game genre. The dialogue system incorporation provides players with opportunities to perform varied actions by selecting their dialogue options thereby locating and digesting the information they will retain from the career path they have chosen to obtain knowledge about. The intrinsic content integration adopts a linear and cyclical approach, (Aldrich, 2004, 2005), embedding paths and activities that may or may not impact the gameplay for the player depending on the player's actions. The pedagogical focus of the game is conveyed through dialogue interaction, for example, with NPCs at the beginning of a level or subsequent engagement with NPCs as the player progresses throughout the level. The player is able to retain knowledge formatively whilst navigating the level whilst solidifying their knowledge when their learning is evaluated summatively post completion of the level.

Figure 5: Dialogue system in the art and animation level

The dialogue system is a primary mechanic that adheres to content integration in the serious game and is used to convey game industry job roles associating details on job roles and skill set requirements for that job position such as hard and soft skills. The importance of the inclusion of the graduate attributes in the game was relevant to make students aware and knowledgeable about the soft skills they will develop through their university experience. In addition to highlighting these generic attributes, it was fundamental to address and illustrate the ones that are specific to various job roles in the games industry. From a game designer perspective, it was important to have a game mechanic that would make these attributes accessible to the player via the gameplay while offering a challenge to increase player engagement. Player collectibles are a common mechanic used widely in AAA games developed within the industry to increase engagement and the time a player spends on a game (Schell, 2020, pp. 231-234). Each of the game's levels, excluding the game studio environment, includes 27 collectibles in relation to generic graduate attributes in addition to ones required to learn about specific game industry job roles. The game mechanic of introducing collectibles to the player had to provide an incentive for the player. To accomplish this via the game mechanics, acquiring these collectibles initiated a levelling up system (e.g., acquiring a certain amount of points via the scoring system). Each of the graduate attributes collected have been assigned a level from 1-4 depending on how many the player collects across all of the four levels. See Figure 6 for the original design plans for the game.

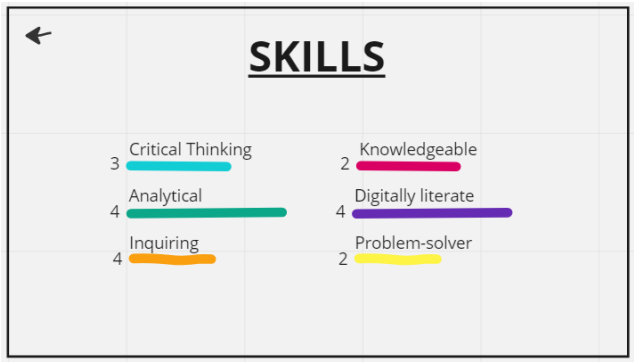


Figure 6: Example of some graduate attributes collectibles (mock-up design)

Assessment Integration

The knowledge retention of the students playing the game had to be concurrently evident during and towards the completion of the various levels. It was important to ensure that there was a clear indication to the player in terms of feedback indicating they have successfully retained the knowledge the have learnt. The game accommodates assessment-based exercises designed to evaluate whether the player has successfully retained the knowledge acquired from the learning content in the game.

Each level formatively assesses the player predominantly through NPC interaction and quizzes. The aim is to assess the player on the retention of knowledge in the job role that they are learning about associated with the games industry. This occurs at the end of each level thereby catering for summative assessment. These summative assessments will be predominately in the form of a quiz allowing the player to remain immersed in that specific game genre whilst being tested in relation to questions associated with a specific games industry job role.

Figure 7 provides an overview on the quiz methods for each level and Figure 8 highlights an example of assessment integration.

	Level	**Quiz Method**
1	Design	Pads Correct answer – progress to next question. Incorrect answer – fall in pit and start at checkpoint of questions again.
2	Programming	XYZ Axis Move block from starting position to the correct answer using the XYZ axis and frames to help guide.
3	Art & Animation	RPG Boss Fight RPG boss fight (player vs pirate ships) with large enemy health bar and player health bar. Correct answer – enemy health depletes. Incorrect answer – player health depletes.
4	Quality Assurance (QA)	Enemies Shoot (subject to development) Fast-paced enemies with answers to shoot. Correct answer – progress to next question. Incorrect answer – player health depletes/ run out of ammo.

Figure 7: Quiz methods introduced as assessment integration

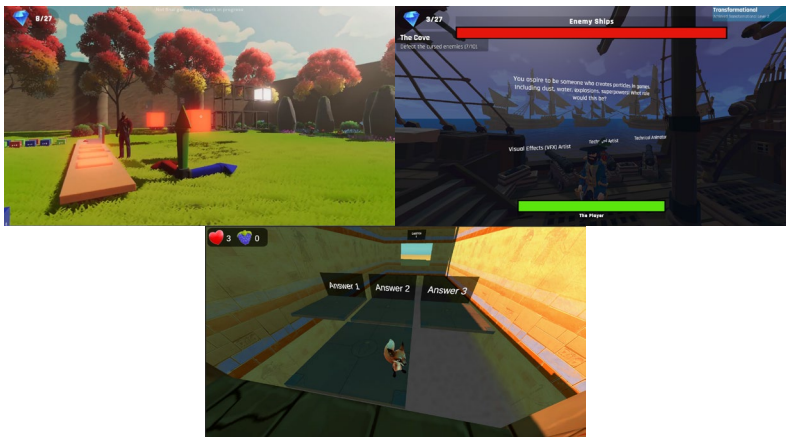


Figure 8: Programming, design and art and animation (work in progress) quiz method assessment integration

Achieving learning outcomes of the game

When undertaking the design and development of the serious game it was relevant to accommodate and incorporate design aspects of fun, engagement, and immersion. The primary aim was to establish core game design theories and techniques with a pedagogical focus of educational theory whilst supporting an aesthetically pleasing, yet familiar environment for the player. The pedagogical theories underpinning the game include problem-based learning, reflection, and intrinsic motivation. The retention of knowledge via the gameplay, mechanics, narrative, and challenge aids to support this pedagogy.

Each initial learning outcome for the serious game are as follows:

- Educate and familiarise the player with the basis environment of a AAA games studio.
- Inform the player about the concept of career pathways in the games industry illustrated through the different roles in a games development team.
- Reflect upon the skill sets required to work in the games industry in addition to what skills to improve upon.
- Reinforce learning through content integration in the game in the form of puzzles, quizzes, interactive dialogue, and feedback.

The identified learning outcomes aid towards accommodating the player in the elements of fun, engagement, and immersion. The serious game design methodology approach proposed by Silva (2019), was adopted as a useful development framework for the serious game (see Figure 8). This framework assisted in identifying the salient components of the serious game such as the levels their associated genres, the game's learning aims and objectives and how the learning outcomes would be met. This would allow informative gameplay approaches to be made and players of the game to reflect on the skill sets required to work within job roles of the game industry. Players' knowledge retention is assessed through the unique quiz designs through summative assessments per level of the game.

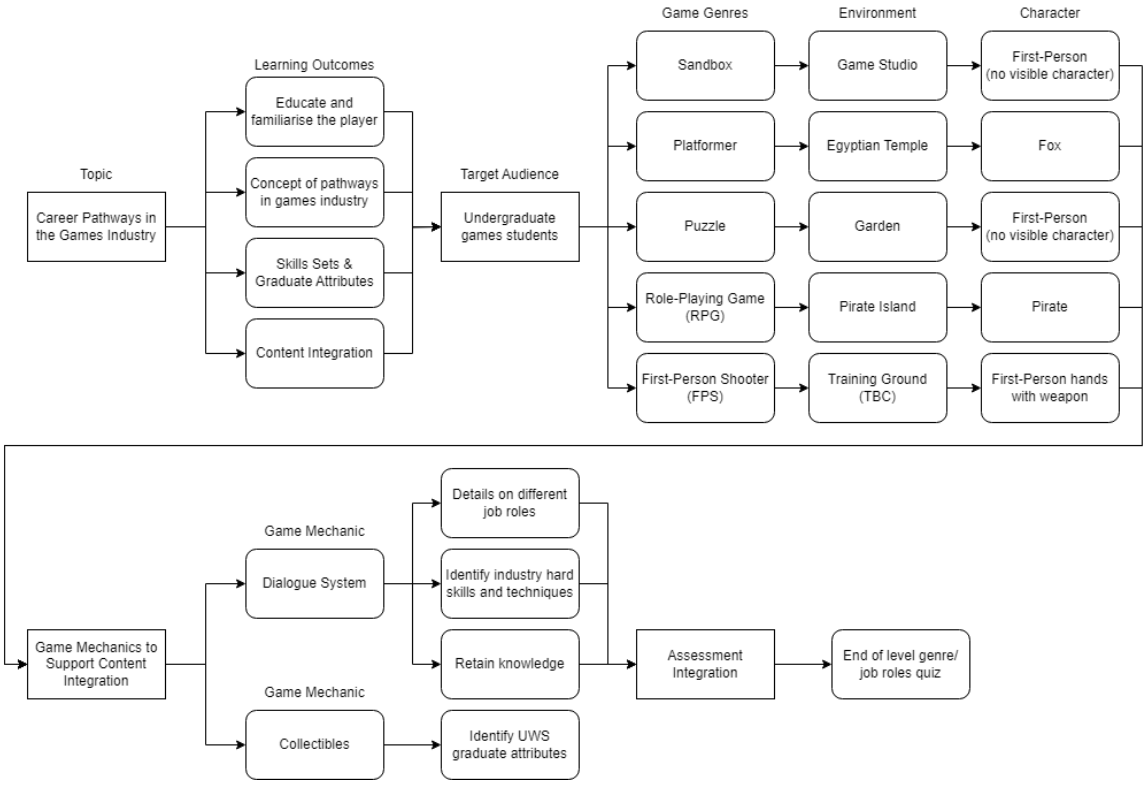


Figure 8: Main steps in defining the aims, gameplay, mechanics and learning activities of the serious game. Adapted from Silva (2019).

6. Conclusion and Future Developments for the Game

This paper has presented the design and development of a serious game to educate and inform computer game development students about the career pathways in the games industry. The game accommodates and embeds

elements of fun, engagement, and immersion, while establishing key game design and pedagogical elements to aid student learning. The serious game is designed to propose a solution to educate and inform students in the games industry about what job role they might want to engage in post their degree and thereby reduce the dilemma some students may face when choosing such a career path. Future directions for this game could be adapted to other disciplines outside of the games industry as an adaptive serious game platform to assist in potential career pathways in other career disciplines such as nursing and midwifery. At the time of writing this paper, the development of the serious game is still ongoing, with the central HUB (Game Studio) and the Quality Assurance (FPS) level yet to be completed.

The serious game will be further evaluated and given to potential games development students during forthcoming academic terms to assess whether the gameplay and mechanics contribute towards guiding and informing game development students in reflecting upon and choosing a career pathway in the industry. This will be evaluated upon first to final year undergraduate students studying computer games development through a series of live gameplay sessions with feedback to the game digested and interpreted through a mixed methods questionnaire. Initial evaluation has however been performed for earlier levels of the serious game by game development students from year one and two, using mixed methods post questionnaires. The evaluation and ongoing results are currently being analysed, with comments for feedback being taken into consideration for the continued enhanced development of the game.

The current serious game is not available due to ongoing development though in the future, will be made available to other game development programmes run at other academic institutions for continued evaluation prior to final release.

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Vocabulary Acquisition in New and Learned Contexts Using Immersive Virtual Reality

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Abstract: Vocabulary acquisition is important for learning a language. Language learners need multiple encounters with a word to add unknown word aspects to their word knowledge or to strengthen their knowledge of previously learned word aspects. Combining vocabulary acquisition with immersive virtual reality (IVR) makes it possible to have such multiple encounters. In IVR, objects representing target words can be shown in the same virtual environment as they were first encountered (*learned context*), but also in a new virtual environment (*new context*). To investigate learning words in either a new or learned context in IVR we built Wics (words in context system). We used Wics to carry out an experiment in which participants could learn 32 Japanese words, represented by 3D objects, in three sessions. In the second and third learning session all words were shown in either a new context, with a changed environment and a changed visual representation of the word objects, or a learned context, where only the placement of the objects was changed. Performance scores for an immediate and a delayed post-test (one week later) revealed no significant differences in performance between conditions. However, there was a tendency towards participants spending more time on learning the words in the learned context condition. We believe Wics to be the first IVR system to provide learners with multiple learning sessions to provide multiple encounters with the same words in different contexts, where learners have control over their own explorative learning, and where the post-tests are inside IVR.

Keywords: Vocabulary acquisition, Immersive VR, Learned context, New context, Dynamic representation, Language learning

1. Introduction

Vocabulary acquisition research is complex and has a multi-dimensional nature. The research varies from theories on how we learn words to multimodal conversational analysis in the wild, where new technologies such as eye tracking facilitate other ways of analysis and gaming provides new forms of interaction (Loewen & Sato, 2017; Godwin-Jones, 2018). What can be learned about a word is more than just the meaning that is connected to it. A word has its own pronunciation and a specific text representation, but it also has other aspects such as in what context you can expect to encounter a word. If more word aspects are understood, then the depth of word knowledge increases (Nation, 2013). Multiple encounters with a word are necessary to add to a learner's word knowledge; this is called word recycling. Words can be encountered in a new context or a learned context (Jeong *et al.*, 2010). In the first case, a learner has not seen the word in the same context before and in the second case, the learner has previously encountered and processed the word in the same context. Here, a context is everything that surrounds a word when it is encountered. Jeong *et al.* (2010) compared videos showing words (text-based) in always the same context (learned context), with videos that visualized words in action (situation-based) in varying contexts (new context). The text-based participants performed exceedingly well when doing a text-based test, where they saw their learned context, but performed badly when they had to recall the word in a new context in a situation-based test. The situation-based learners did relatively well in both learned and new contexts.

An emerging focus within language learning is the combination of language learning with immersive virtual reality (IVR). IVR is a technology that allows many contexts to be easily generated. It provides a person with a full 360-degree experience by wearing either a head-mounted display or with surrounding projections. IVR has characteristics that create new opportunities for second language (L2) learners, including creating a feeling of interacting with an object inside the virtual environment (VE) or conversing with a non-player character (NPC) to counter learner anxiety (Collins, Vaughan and Cullen, 2020). IVR is also able to quickly bring variations into a VE or to change the whole VE. However, to our knowledge all previous research on vocabulary acquisition in IVR has worked with only one VE for each participant in each condition.

Building on the earlier mentioned necessity for multiple word encounters in different contexts for adding to the depth of word knowledge, our research question is: *What are the effects of recycling words in IVR in learned or new contexts on retrieving words when encountered in a new context?* We define *the context* as the virtual environment including specific visual representations of words as objects. Retrieving words is the ability

to link these objects to the (phonetically) proper L2 word. To recycle words in IVR in new and learned contexts, and to evaluate this in a new context, we built a system called Wics, short for *words in contexts system*. We used it in an experiment to answer our research question. Below, we first describe related work to place our study and contributions in a wider context, then introduce our system and study, describe the results of this study and end with a discussion and conclusion.

2. Related Work

For building Wics and setting up our study we looked at related work that, like ours, (i) presents participants with predetermined target words inside a VE in IVR to study and learn, and (ii) tests participants on words that they have encountered in the VE. This resulted in 16 related environments, not all discussed in this paper. Most closely related to our own work are projects that take an *exploration-based approach* to vocabulary acquisition. In these studies, participants can freely explore a VE in which target words are placed as visual objects. VEs typically correspond to familiar environments such as a living room (Ebert, Gupta and Makedon, 2016; Garcia *et al.*, 2019), kitchen (Legault *et al.*, 2019; Jia and Liu, 2019), zoo (Legault *et al.*, 2019), airport customs (Dobrova *et al.*, 2018), classroom (Cho, 2018) or supermarket (Collins, Vaughan and Cullen, 2020).

Various strategies are employed to make participants aware of target words within the environment. For example, exclamation marks hover over the target words (Ebert, Gupta and Makedon, 2016), objects are highlighted in blue (Garcia *et al.*, 2019), or gems float next to target words (Legault *et al.* 2019). In contrast, in another VE Legault *et al.* (2019) prevent drawing attention to the target words to encourage exploration, and only point out missed target words with arrows after some time has passed. Cho (2018) uses arrows on the floor to guide their participants past all target words, so participants are less free but can study the target words at their own pace. The commercial exploration-based game used for vocabulary acquisition by Alfadil (2020) places players in a VE (e.g. airport, cafe, cinema) where an NPC asks them to find specific objects.

Besides exploration, vocabulary acquisition can also be done through *conversation*. The IVR experience of Dobrova *et al.* (2018) consists of two VEs, one exploratory-based and one conversation-based. In the latter, participants interact with a virtual customs officer to learn new words and test their word knowledge. Other studies use a purely conversation-based approach. For example, the IVR environment of Cheng, Yang and Andersen (2017) is a Japanese teahouse with NPCs that provide different types of dialogue.

One line of research on vocabulary acquisition in IVR is based on *embodied cognition theory*, which revolves around the concept that cognitive processes (including language learning) are grounded in the body's interaction with the world (Vázquez *et al.*, 2018; Fuhrman *et al.*, 2021). For example, Vázquez *et al.* (2018) connect the movement of drawing specific symbols to target words.

Six of the studies compared word learning in IVR to learning in a non-IVR condition. The control condition in such studies varies between traditional methods (Legault *et al.*, 2019; Ebert, Gupta and Makedon, 2016; Vázquez *et al.* 2018; Alfadil 2020), a desktop equivalent (Cheng, Yang and Andersen, 2017), or gameplay videos (Tai, Chen and Todd, 2020). In some studies, participants in the IVR condition perform significantly better on the post-test (Legault *et al.* 2019; Alfadil, 2020; Tai, Chen and Todd, 2020). Sometimes they perform only slightly better (Cheng, Yang and Andersen, 2017), and in some studies they perform significantly worse than participants in the non-IVR condition (Ebert, Gupta and Makedon, 2016; Vázquez *et al.*, 2018). However, studies that looked at retention with a delayed post-test all found that IVR participants had a significantly higher retention rate than non-IVR participants (Ebert, Gupta and Makedon, 2016; Vázquez *et al.*, 2018; Tai, Chen and Todd, 2020). Thus, after some time had passed there was a larger word loss for non-IVR participants while IVR participants still remembered most of their learned words.

The discussed studies show promising results on retention of using IVR but did not recycle words or evaluate on recycling words. This raises the question if and how presenting learners with recycled words in either new or learned contexts might affect learning. This is what we focus on in our work.

3. Materials and Method - Experiment With Wics

Overall, the studies above indicate that IVR participants score slightly more often significantly better on post-tests than non-IVR participants, but the retention of the IVR group is always significantly higher. From this we conclude that a non-IVR condition can be excluded if the focus of a study lies on the long term effects of using IVR for vocabulary acquisition and participants are also tested on retention.

Recycling words helps a learner to learn more word aspects and to better retrieve words from memory. During explicit learning words are often recycled in the same context, for example when using flash cards, but words in everyday use are applied in a variety of new contexts and not just one learned context. A first video-based comparison already showed the possible effectiveness of including such variation in learning (Jeong *et al.*, 2010). This opportunity of learning words in various contexts, combined with recycling words, fits well with the ease of IVR environments to represent objects in various ways and in an explorative approach. To test the effect of learning in a new context we thus set up a study with an IVR environment where we compared the use of a *new* to a *learned context*. Balancing the needed attention span, the time needed for implementation and testing, and the possible effect of the intervention, we chose two new environments for the new context intervention. In these new environments both the objects and the surroundings were changed.

Each word has word aspects, such as its pronunciation or other words that occur with that word, and knowing more word aspects increases a learner's word knowledge depth (Nation, 2013). There are too many word aspects to learn all at once, so we limited the number of word aspects to present to participants to five. Learners tend to first establish the form-meaning link of a word so they can read or hear the L2 word and understand the meaning (Schmitt, 2008). Therefore we provided participants with (i) the sound of a word, (ii) the written form of a word and (iii) the meaning of a word, so they would be able to establish a form-meaning link. As Wics shows different visual representations of words in different contexts, we also included (iv) the concept of a word. To also include (v) where and when the word is likely to be encountered, we chose environments, objects and their location to match with what can be expected in the real world.

The independent variable of the experiment is the context in which words are repeated for learning a second and third time (i.e. new or learned), see Table 1, and the dependent variables are the test scores for the post-test and delayed post-test, how often each target word is studied, and the time spent in the VEs. Between the environments, participants had to take a break to not get overwhelmed through extended IVR use and from learning. The delayed post-test took place one week later.

Table 1: Setup of the experiment for both contexts

Learned context	New context
Learning environment 1	
Environment A Object representations A Object locations A	
Learning environment 2	
Environment A Object representations A Object locations Y	Environment B Object representations B Object locations B
Learning environment 3	
Environment A Object representations A Object locations Z	Environment C Object representations C Object locations C
Posttest	
Environment D Object representations D Object locations D	
Delayed posttest	
Environment E Object representations E Object locations E	

3.1 Wics

To broaden our potential user pool, we used a social IVR environment for our system, limiting thresholds such as installing programs before participating. From the platforms that provided active world-building we chose *Neos VR* (https://neos.com/) for its all-in-one solution and ability to visualise the world-building directly within the environment in IVR. Alternatives such as *VRChat*, *Sansar*, *Rec Room*, and *AltspaceVR* have a larger user base but less interaction capabilities.

Based on the personal expertise of the first author we decided to investigate learning Japanese words, similar to seminal work from Rose and Billinghurst (1995) and later Cheng, Yang and Andersen (2017). Based on related work showing that some participants could learn as many as 30 words in 20 minutes (Legault *et al.*,

2019), but also to prevent clutter in a reasonably sized environment, we decided to have 32 target words. Similar to Ebert, Gupta and Makedon (2016) we linked words to virtual objects in the environment. Where they used exclamation marks to indicate target words we instead, to further reduce clutter, offered users the possibility to *point and click* the objects, triggering words both in spoken and written format together with a written English translation. To provide an indication of where any missed objects are in the world, we provided a toggle to highlight these. This way, users could go through the experience at their own pace in an exploration-based manner while minimising frustration.

3.2 Worlds, Words, and Items

We selected five publicly available worlds that could be edited in 3D, that were suitable to contain a collection of varied objects, and that looked different enough to provide varying contexts, see Figure 1. The order and role of each environment balanced low poly and more realistic visualizations, fitting variation in learning, revisiting, and testing.

Figure 1: The selected worlds with 32 objects: A) an island, B) a bedroom with garden, C) an apartment, D) a theatre, and E) a barn, and an example of a triggered target word

To select the 32 target words, we excluded words of which multiple instances could be found in the environment (such as doors or stones, e.g. see B in Figure 1), and removed single objects that could be mistaken for a target word. We made sure to include short (one, two syllables), medium (three syllables), and long (four syllables) words and added a set of loan words from English (e.g. *naifu* for knife) to provide words that participants could quickly learn to create a feeling of success. Finally, pragmatically we needed at least five different visual representations of each object, which further reduced our word set. Our final word list was: avocado-*waninashi*, bag-*kaban*, ball-*tama*, bed-*beddo*, boat-*fune*, book-*hon*, bookcase-*hondana*, broom-*houki*, butterfly-*chouchou*, camera-*shashinki*, car-*kuruma*, chair/stool-*isu*, chest of drawers-*tansu*, coin-*kouka*, couch-*nagaisu*, desk-*tsukue*, earth-*chikyuu*, fish-*sakana*, flower-*hana*, garbage bin-*gomibako*, glasses-*megane*, key-*kagi*, knife-*naifu*, lamp-*ranpu*, mushroom-*kinoko*, pinecone-*matsukasa*, rug-*juutan*, shoe-*kutsu,* table-*tebburu*, teapot-*chabin*, telescope-*bouenkyou* and television-*terebi*.

In the two test worlds, all objects have a label assigned with a text field, see Figures 1D and 1E. After pointing and clicking on it, a text can be typed in the field using the platform's virtual keyboard. Participants are transported between the different worlds through portals. Inside the worlds, participants can choose their preferred manner of locomotion (e.g. teleport or walk with a controller) and whether to perform the test sitting or standing. Furthermore, there is a small introduction room, where the participants can learn how to activate objects and find not yet found items. The Wics environments are publicly accessible in Neos VR, which is a free platform available through Steam, using the following URL: https://tinyurl.com/4mzth2bh.

3.3 Participants and Procedure

Experienced IVR participants were sought within the Neos VR community. A small description of the experiment was provided, including specifics regarding the expected duration (an hour) and how to sign up. A promotion room in Neos VR contained a textual description of the experiment, a link to the consent form, three L2 word objects to learn, a portal visualisation and a promotional poster. Interested participants could open a consent form and an information document with detailed specifics about the experiment. Participants were also sought through word-of-mouth. Our study was approved by our faculty's ethics committee (RP 2021-223).

Of in total 26 participants who started the experiment, four did not complete the delayed post-test and were excluded from the results. Six participants in the learned context condition and nine participants in the new context condition were experienced IVR users. They participated through Neos VR without further assistance from a researcher. Five participants in the learned context condition and two participants in the new context condition were non-experienced IVR users. They participated in a physical room with a researcher present. Age ranges were 21-25 years (eight participants), 26-30 years (eleven participants), 56-60 years (two participants) and 61-65 years (one participant)

3.4 Equipment

Neos VR user participants used their own hardware for Neos VR. The other participants travelled to a location with a room with an HTC VIVE (2016). The researcher kept an eye on what happened in IVR from a desktop in one corner. The space was cleared so the participant could move their arms around freely. A chair stood in the middle of the IVR play area for the participant to sit on if they preferred.

3.5 Stepwise Procedure for the Participants

Non-experienced IVR participants received a short explanation regarding the IVR introduction room they would start in. While the participants then went through the introduction room, the researcher stayed present in the physical room, monitoring them and offering guidance when necessary. Once the participant felt like they understood the interactions, the researcher left the physical room. Experienced participants, who did the experiment in Neos VR, received the experiment world through the Neos VR message system. They also started in the middle of the introduction room. When the participants had finished the introduction, the portal to the first world (learning environment) was opened.

The participants then were free to explore the environment and activate target objects to hear and read their L2 word plus an English translation. After the participants had found all the target objects in the learning environment, they were forced to take a short break of minimally three and maximally 15 minutes in a virtual break room, where they could watch a relaxing video. Participants could also take off their headset.

Figure 2: The toggle button to indicate missed items and open a portal to the next world

The experiment ended in a saving room filled with information in two parts: first, asking the participant if they wanted to get reminders about the second part of the experiment that must be done a week later; second, explaining to the participant how to send their data to the researcher before closing the experiment world.

The data the participants needed to send were their filled-in answers from the test environment and logs of use of the learning worlds. After doing so, they were reminded that they should no longer actively try to learn or repeat the words in their head.

3.6 Analysis

Points were assigned by the first author: 1 point if the answer was phonetically correct, 0.5 points if it was almost correct (i.e. one syllable wrong or missing), similar to Ebert, Gupta and Makedon (2016) and Fuhrman *et al.* (2021). If participants already knew words prior to participating, we corrected the score to not include those words, dividing the initial score by 32 minus the N words that were known prior to participating. For example, if a participant knew six words beforehand, and scored 18 points on the words they did not know beforehand, then their performance score percentage was 18/(32−6) 100% = 69.23%, whereas their score would have been 24/32 100% = 75% without the correction.

The performance and retention scores seem to be close to normally distributed continuous data but are expected to break parametric assumptions due to a skewed data set. Therefore, we treated the performance scores as ordinal data and used a non-parametric test to compare the independent new and learned context conditions: the Mann-Whitney U test (Morgan, 2017). We also used the Mann-Whitney U test to compare the total time spent in the learning environments, the total time spent in the break rooms, the performance scores for the post-test and word retention.

4. Results

Wics worked mostly as intended and was received well. Only two of the 22 participants experienced a world crash in Neos VR. In both cases, the preceding VEs were quickly traversed a second time until the point where the crash happened. The times inside the learning VEs and break rooms of these two participants were left out of the results, while their test scores were included.

Table 2 shows the max score, score, and performance percentage per participant per condition, as well as the median and standard deviation between participants for both conditions. The max score refers to the maximum score a participant could get given the number of words they knew beforehand. The participants' performance on the post-test did not differ significantly between the learned context condition (Mdn = 89.06) and the new context condition (Mdn = 79.69), U = 58.5, z = -0.1286, p = 0.8977. Table 3 shows the max score, score, performance percentage, and retention percentage per participant per condition, as well as the median and standard deviation between participants for both conditions. Figure 3 shows the box plots of both the performance and the retention percentages of both conditions. The participants' performance on the delayed post-test (retention) did not differ significantly between the learned context condition (Mdn = 76.92) and the new context condition (Mdn = 72.73), U = 75, z = 0.9053, p = 0.3653. Table 4 shows the total time spent in rounded-down minutes in the learn and break environments per participant per condition, as well as the median and standard deviation between participants for both conditions. Time spent by participants in the learning environments did not differ significantly between the learned context condition (Mdn = 47.5) and the new context condition (Mdn = 26) during the experiment, U = 73, z = 1.6996, p = 0.08921. Time spent by participants in the break environments also did not differ significantly between the learned context condition (Mdn = 23.5) and the new context condition (Mdn = 16) during the experiment, U = 74, z = 1.7789, p = 0.0752.

Table 2: Post-test scores and performance of participants per condition

Learned				New			
Participant	Max score	Score	Perf. (%)	Participant	Max score	Score	Perf. (%)
L1	32	14	43.75	N1	25	15.5	62.00
L2	25	24	96.00	N2	32	25	78.13
L3	32	28.5	89.06	N3	32	25.5	79.69
L4	25	19.5	78.00	N4	31	30	96.77
L5	32	16.5	51.56	N5	32	30.5	95.31
L6	32	28.5	89.06	N6	20	19	95.00
L7	32	29.5	92.19	N7	32	31.5	98.44
L8	32	30	93.75	N8	32	7	21.88
L9	32	30,5	95.31	N9	28	24	85.71
L10	32	6.5	20.31	N10	32	17.5	54.69
L11	32	30	93.75	N11	28	16.5	58.93
Median	32	28.5	89.06	Median	32	24	79.69
Mean	30.73	23.41	76.61	Mean	29.45	22.00	75.14

Table 3: Delayed post-test scores and performance of participants per condition

Learned	Max score	Score	Performance (%)	Retention (%)
L1	32	14	43.75	100.00
L2	25	19	76.00	79.17
L3	32	22	68.75	77.19
L4	25	18.5	74.00	94.87
L5	32	9	28.13	54.55
L6	32	18	56.25	63.16
L7	32	22.5	70.31	76.27
L8	32	22	68.75	73.33
L9	32	30	93.75	98.36
L10	32	5	15.63	76.92
L11	32	10.5	32.81	35.00
Median	32	18.5	68.75	76.92
Mean	30.73	17.32	57.10	75.35

New	Max score	Score	Performance (%)	Retention (%)
N1	25	13	52.00	83.87
N2	32	12	37.50	48.00
N3	32	14.5	45.31	56.86
N4	31	22.5	72.58	75.00
N5	32	23.5	73.44	77.05
N6	20	16	80.00	84.21
N7	32	30	93.75	95.24
N8	32	3.5	10.94	50.00
N9	28	16	57.14	66.67
N10	32	9.5	29.69	54.29
N11	28	12	42.86	72.73
Median	32	14.5	52.00	72.73
Mean	29.45	15.68	54.11	69.45

Table 4: Time spent in the learn and break environments per participant and condition

Learned	Learn	Break
L1	-	-
L2	59	27
L3	32	19
L4	19	19
L5	71	27
L6	52	29
L7	65	20
L8	54	40
L9	43	18
L10	9	20
L11	36	37
Total	440	256
Median	47.5	23.5

New	Learn	Break
N1	45	35
N2	31	13
N3	20	9
N4	50	30
N5	38	23
N6	25	17
N7	24	15
N8	-	-
N9	24	12
N10	18	11
N11	27	22
Total	302	187
Median	26	16

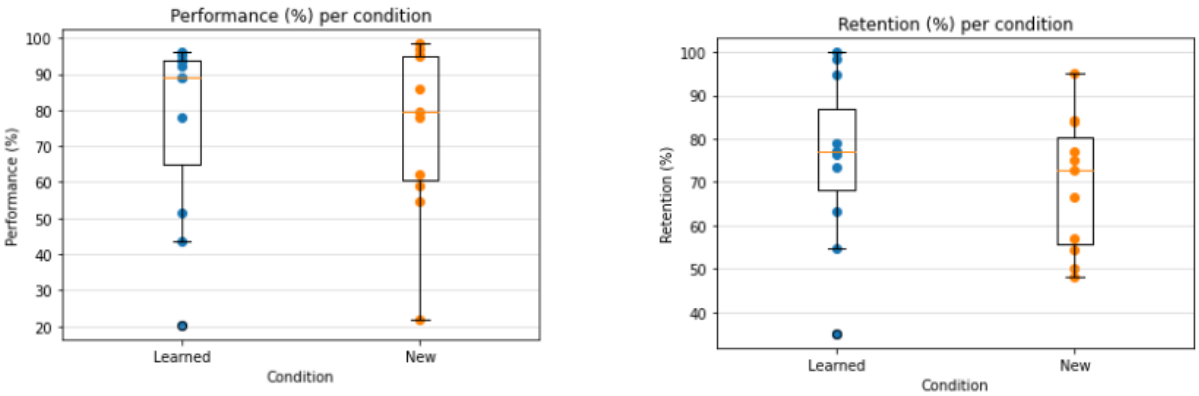

Figure 3: Box plot of both the performance (left) and retention (right) percentages of both conditions

5. Discussion and Conclusion

In this research, we compared recycling words in IVR in a new context, where each of the three learning sessions took place in a different VE with changed visual representations of the words, and in a learned context, which was kept the same for each learning session. The two post-tests happened in a new context, also within IVR: the first post-test immediately after learning, and the delayed post-test a week after the first. We built a system called Wics to do the experiment. Each learning environment in Wics contained the same 32 target words, represented as visual objects. The participants could explore the environment and activate

target objects to hear and read their L2 word (in Japanese) plus an English translation. Comments by the participants indicated the system was overall well received. For instance, participant N6 mentioned: *it was a very interesting experience - certainly richer than simply trying to learn a list of words!* With mean scores of 77% (learned context) and 75% (new context), results regarding the new words learned were similar and even slightly better than those by Cheng, Yang and Andersen (2017), the other IVR for learning Japanese, where participants had a mean score of 4.77 out of 8 possible words = 60%.

We found no significant difference between conditions for performance on the post-test, nor on retention, measured via the delayed post-test. This differs from the expected generalization of the results from Jeong *et al.* (2010), which showed participants who watched text-based videos within the same context (learned context) performed badly when they had to recall the word in a new context in a situation-based test. However, we see that our learned context group spent substantially more time in the learning environment. This difference was not significant at 95% confidence but would be at 90% confidence. We used Spearman's Rho to informally investigate a possible correlation between total learning time and performance on the post-test ($rs = 0.33434$, $p = 0.14965$) and the total learning time and retention ($rs = -0.03009$, $p = 0.8998$). The results suggest that a longer learning time might have benefited performance on the first post-test, but not retention. This also fits with the response of one participant: *I spent a lot more time in the first one, so it's not too surprising to me that my memory of that one is stronger than the subsequent two* (N6). This leaves open the possibility that learning in a new context prepared participants better for retrieving words in the post-test (in a new context), but that this benefit was offset by participants in the learned context condition learning for a longer period. Furthermore, we used the same type of audio for all contexts, whereas some participants indicated an unanticipated auditory memory (e.g. N5: *I'm generally not a very visual thinker, so for most of them I was just trying to recall the sounds of the words*).

Perhaps our IVR provides too many new word aspects at once, where the visual representation word aspect is not one of the primary word aspects stored in memory for learners (Nation, 2013), and is only stored minimally and mostly lost over time. Perhaps offering learners ample opportunity to process words between learning sessions leads to multiple word aspects being stored more equally in memory.

To our knowledge, Wics is the first system to provide learners with multiple learning sessions, provide control over learning by activating an indicator for missed words, and offer post-tests inside IVR. For our study, we built on a comprehensive overview of IVR-based language acquisition with 16 papers (cf. the literature review by Palmeira *et al.* (2020), encountered later in our research, with nine papers). A full description of our literature review is outside the scope of this conference paper, so we refer the reader to an underlying master thesis (Bergsma, 2022). Similar to related studies, our participants showed enthusiasm for learning in Wics, discovering which virtual environment would await them next. The possibility of IVR to change VEs with ease should not be overlooked by language learning researchers as it can keep motivation up while providing learners with many contexts to learn, whether they switch contexts consecutively or repeat one context a few times. Furthermore, as participants showed a clear enthusiasm for going back to IVR to do the delayed post-test, other studies might consider doing their post-test(s) also in IVR, to base the results on a test method that complements the learning method that is studied.

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Maestro Martino: Designing a Historic Escape Room With Primary School Children

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Abstract: Educational escape rooms are being used in all school sectors and in many different subjects across the globe. In most documented cases, escape rooms are designed by teachers and played by students. This paper presents the case study of a primary school class that designed and developed an escape room for both adult and young players in connection with a regional event connected to a historical celebration. The project spanned over the whole school year and included a learning phase, the production of support materials (as comics) and eventually the design and development of the escape room, which was finalized by a local association. After its installation in the ancient local prison, the escape room enjoyed the visit of over 600 players, including tourists, families, groups of friends, and school classes, representing a successful example of open school game design project. The paper presents the key phases of the project: requirement analysis, escape room design (including narrative, puzzles, game-flow and props), escape room implementation, and assessment, with a focus on how to manage complex game design with young children.

Keywords: Escape room, Primary school, Open school, Game design

1. Background

According to Nicholson (2016), escape rooms are "live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time" (p. 18). Commercial escape rooms are often developed around a theme and blend different types of challenges, including those that require teamwork and collaboration.

The use of Escape Rooms (ERs) as a game-based learning activity can be considered a relatively new but not anymore uncommon educational practice internationally. Several educational ER experiences and studies have been reported in higher and adult education (Fotaris and Mastoras, 2019; Mijal et al., 2020; Veldkamp et al., 2020), while only a limited body of work explores the same topic in middle-school, primary school or kindergarten (Fotaris and Mastoras, 2019; Hod-Shemer and Dabush, 2020; Babazadeh and Frigerio, 2021; Babazadeh, Botturi & Reggiani, 2022).

Educational ER support discovery-based learning in a playful context, and are usually framed as examples of active, collaborative, team-based and/or game-based learning (Veldkamp et al., 2020). In most documented cases, teachers integrate ERs as learning activities for their students (Botturi and Babazadeh, 2022). The games are either designed by teachers themselves or adapted from commercial or open repositories (e.g., breakoutedu.com) and played by students. While not yet conclusive, research evidence suggests that ERs are powerful instructional devices for both subject matter learning and life skills or transversal competences development (Babazadeh et al, 2022).

1.1 Designing Escape Rooms With Pupils

This paper takes a different perspective: it does not focus on the use of an educational ER for game-based learning, but on a project-based learning experience designed around a collective game design process. More precisely, it presents the case study of a primary school class that designed and developed an escape room on historical content for both adult and young players in connection with a regional event.

While proposed in ER-related handbooks (Botturi and Babazadeh, 2022), such an approach is much less documented in the literature. To our knowledge, only two recent studies illustrate similar cases. Karageorgiou et al. (2019) analyzed a digital VR-based ER school design project in a vocational high school. The process included 20 steps, from design to marketing, and resulted in high satisfaction and learning. Botturi and Babazadeh (2021) presented the case study of a lower secondary school project, in which the students, a few weeks before the breakout of the Covid-19 pandemics, developed an educational ER on viruses. In that study, the authors analyzed both subject-matter learning (for which positive results were reported) and the development of leadership and communication skills (which were only mildly improved).

The present case study brings three distinctive and innovative elements: it presents the collaborative design of an educational ER as a project-based learning experience; it took place in a primary school, which is an uncommon setting for such an endeavor; and it was embedded within a wider collaboration of the school with an external and independent non-profit association organizing a regional cultural event.

The intent of the paper is threefold: (a) confirming that the design of an escape room can represent a suitable challenge for project-based learning; (b) illustrating how the collective design of an escape room can be practically arranged in primary school; (c) documenting how game design as a learning activity can provide opportunities for opening the school and connecting with the environment.

1.2 Celebrating Maestro Martino

In the XV century, Maestro Martino (born Martino De Rubeis) was chef at the court of the Sforza in Milano, and later in Rome private cook of two Popes, Paolo II and Sisto IV. Known as The Prince of Cooks, he is the author of *Libro de Arte Coquinaria*, the first recipe book in the Italian Renaissance. Few know that this artist and innovator was born in Grumo, a small village in Valle di Blenio in Switzerland.

For celebrating his 500th anniversary, a local association (Blenio Bellissima; https://bleniobellissima.ch) developed a concept for connecting exhibitions and events in the region, including *gourmet hikes* and Renaissance dinners in local restaurants, translating and reviving Maestro Martino's original recipes with the aid of contemporary chefs. A teacher at the local school took up the challenge and proposed his Grade 3 class of 16 pupils (9 boys and 7 girls) the development of an ER about Maestro Martino to be included in the official celebration program. The goal was making it a learning experience through which the players would learn the story and importance of Maestro Martino. The author of this paper was invited as expert ER designer to support the project.

The case study was designed as an ongoing participant observation and documentation of the design process and of the underlaying learning process, in which the author was engaged as reflective practitioner (Iacono et al., 2009). The design process was documented through the collection of pupil-produced artefacts; feedback was collected from the teacher at key moments in the process. Given that no data was collected from the pupils, according to the author's home institution, no formal approval of the ethical committee was required.

2. Designing an Escape Room With Pupils

The ER design project spanned over the whole school year. The opening of the ER to players was scheduled for the first Saturday after the end of the school year in June 2022. The design was structured into 5 phases, as illustrated in Figure 1:

1. Visit and requirements analysis;
2. Learning content;
3. Learning to design;
4. Design for learning;
5. Development.

The central phases (2-4) were conducted with the class; phase 1 was managed by the teacher and the author of this paper, while phase 5 was managed by the organizing association.

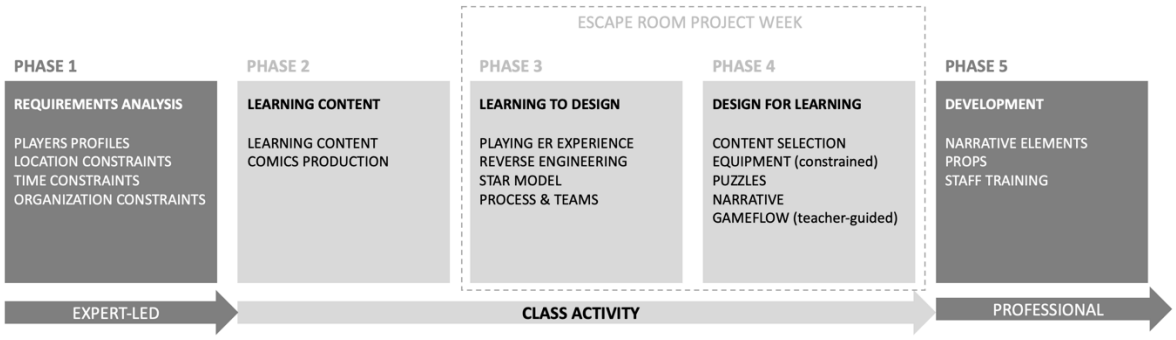

Figure 1: The five design phases and their main outputs

2.1 PHASE 1: Requirements Analysis

The requirements analysis was conducted by the teacher and the author of this paper with the organizing association. The ER had to be designed for two types of players: (a) small groups of tourists, both adults and families; and (b) primary and lower secondary school classes. It should last in both cases about 45 minutes. This meant having two versions of the ER: one with more complex puzzles and language for the former target group, and one with easier puzzles (or more hints) and simplified language for the latter.

The selected location for the ER was the House of the Landfogti, a 500-year-old stone building which hosted the German-speaking ruling family of the valley in the XV century. The House hosts a local history museum, and the prison cells of the House, located in the first floor, were made available for the ER. A visit to the location allowed identifying some constraints: the space was divided in two small non-communicating rooms, and no physical lock-in was possible. No video system was available, so that remote assistance could not be implemented.

Moreover, the ER would be managed by the museum staff on top of their regular duties. This meant that the ER should require only a few minutes for rebooting and that the introduction to the game should be self-explanatory. These requirements were written and agreed upon and kept for phase 3.

A second visit to the location was organized with the pupils, so that they could measure the available spaces and see the historical environment that would host their escape room.

2.2 PHASE 2: Learning Content

The class engaged in the ER design project had of course to first learn about its content, i.e., the history of Maestro Martino. This was achieved in the first part of the school year (October-January) under the guidance of the teacher and was framed as a media project: the pupils engaged in the design and production of a comic book presenting the history of Maestro Martino: after reading historical materials and visiting the key places in the region, they wrote the text, collected pictures, created *ad hoc* costume illustrations and finally edited the comic book (Figure 2), which was the included as a support material in the ER.

Figure 2: Sample Page Of The Comic Book of Maestro Martino

2.3 PHASE 3: Learning to Design

Phase 3 and phase 4 were scheduled as a block escape room project week in March 2022, co-designed and co-led by the class teacher and the author of this paper.

Phase 3 was condensed in the first 1,5 days on the week: its goal was creating shared experience and understanding of what an (educational) escape room is and to provide the conceptual framework required to carry out the design. As many pupils never played an ER, it started with playing an educational ER from BreakOutEdu.com on sustainability titled *Save the Earth!*, and then trying to reverse engineer it, i.e., identifying and describing the key elements that compose and ER. Pupils easily identified the *narrative, puzzles* and *equipment* elements, and also, with some help, the *learning goal* of the ER. Only after some discussion they

managed to focus on the *game-flow*, i.e., on the actual structure and organization of the ER. Such reverse engineering was structured according to the Star model (Botturi & Babazadeh, 2020; Figure 3), which was then kept as main reference for the design. Other models were also considered like the Experience pyramid model (Heikkinen & Shumeyko, 2016) and Room2Educ8 (Fotaris & Mastoras, 2022), or the process described by Karageorgiou et al. (2019). The star model was preferred because it has a limited number of key elements and clearly distinguished between design (the star) and context (the outer circle) elements.

Figure 3: The star model for educational escape room design (from Botturi & Babazadeh, 2020).

The experience with the ER from BreakOutEdu.com was also useful to let pupils see how an ER session works (presentation, rules of play, narrative introduction, game, debriefing) and handle padlocks, boxes and hasps – the materials that they could also use in the project.

2.4 PHASE 4: Design for Learning

Phase 4 took the rest of the project week, and its aim was twofold: (a) designing the ER, and (b) producing a full set of draft materials. This was indeed the most challenging part of the process, as it included the actual design work, and was carefully organized and managed streamlining the Star model elements, as illustrated in Table 1.

The learning goals identified in step one included three domains:

- Factual knowledge about Maestro Martino: where and when it was born, the title of his book and when it was written, in what cities he worked and for whom.
- Curiosities about the recipes, including that time was measured in prayers and that common ingredients had different names than today.
- Eating habits and manner, in particular referencing the “rules of the table” supposedly written by Leonardo in the same period, that illustrated how people should behave when attending an official dinner.

Two ER kits (from BreakOutEdu.com and from MyEscape.ch) were available, along with a few additional elements provided by a local ER company (a magnetic lock box, a battle with padlock cork, a 3-wheel coding system and a few additional locks). Differently from what is usually done, the physical materials of the ER were taken as primary constraints in the design in step 2, i.e., they were presented right away to the pupils and were used to determine the format of solution codes. This decision made the development of puzzles easier, as provided a clear focus to the groups, which had to work on a clearly defined issue like: “develop a puzzle that can be solved by knowing X, and that generates a code of format ABC”.

Pupils created very effective puzzles; the biggest challenge was writing down the ER rules, the hints and the narrative in a formal and clear way. The teacher’s main role in this phase was providing advice and then helping to formalize the pupil’s products. Pupils were also eager to include in the ER some *red herrings*, i.e., false or

misleading hints; for example, some very complex but useless math problems were hung on a wall along with an irrelevant old-looking map of France. The final game flow structure of the ER is illustrated in Figure 4.

Table 1: Organization the ER design (phase 4)

Step	Design element	Goal	Approach
1	Learning	Selecting knowledge items to be learned by the players	Whole class: review of the comic book Personal annotation of key/important elements Whole class: for selecting knowledge items
2	Puzzles	Developing puzzles related to one knowledge item selected in phase 1	Teacher-defined groups: each group picks one knowledge element and one of the available padlocks. Puzzles are tested first with classmates, then with pupils form other classes.
3	Narrative	Developing the ER narrative.	Each group proposes one draft narrative. The whole class selects the best one, which is then further developed by the proposing group.
4	Game-flow	Designing the game-flow for the ER, connecting all puzzles	All puzzles are represented on the blackboard; the expert leads the discussion about how to connect them; a final ER map is drawn.
5	Equipment	Listing all required equipment for the escape room; producing draft materials for puzzles, rules and narrative.	Each group develops the materials for their own puzzle, including hints. Groups that finish earlier make a drawing of how the ER would look like, listing ideas for props.

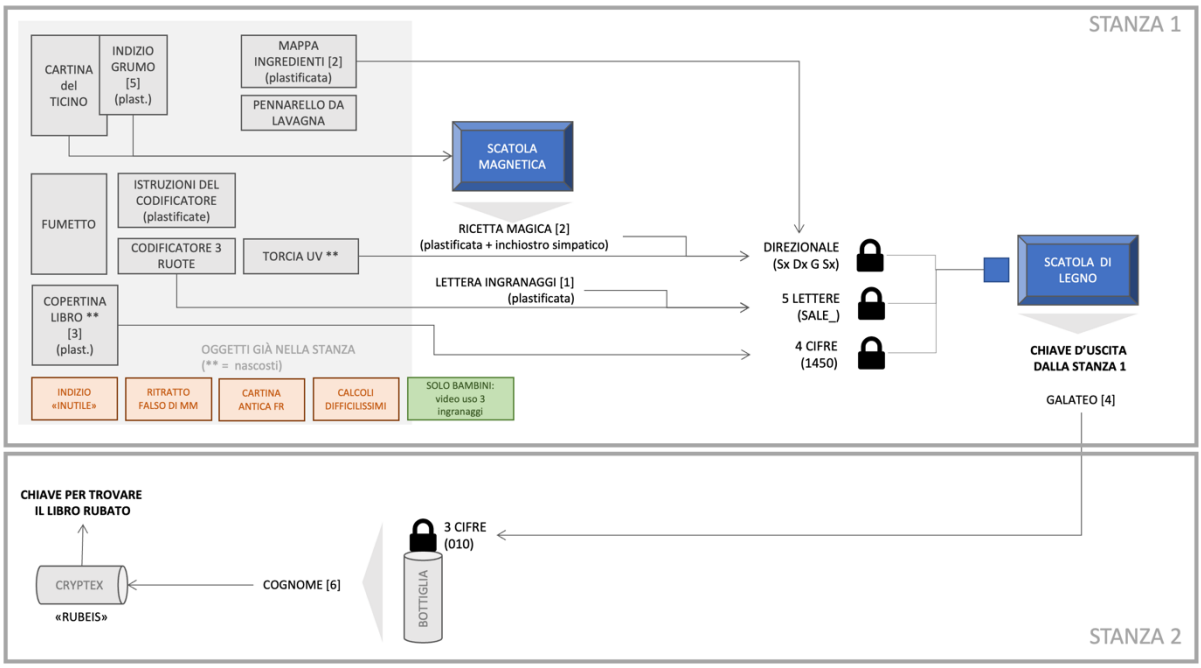

Figure 4: ER game flow

Testing is paramount in ER development just like in any game development process (Botturi & Babazadeh, 2022). In this case, puzzle testing was organized in three tiers: (a) already during development, in step 2, puzzles were tested by classmates, using paper-based draft materials; (b) at the end of step2, pupils of other classes were

invited to “open locks”, and they tested the puzzles using the final materials; (c) on the morning of the last day in the project week, groups of pupils from the terminal class were invited to test out the whole ER.

During the third testing phase, the pupils who designed the ER participated in turns, in the role of narrator, presenter of rules, and observers. After each round feedback was collected, and some elements were fine-tuned, especially the ER rules and some hints, which seemed barely understandable. This final testing also gave the opportunity to adjust the time limit.

The output of phase 4 was a fully functional educational ER, with all materials in low quality, as they included basically school-quality copies of printed materials (e.g., the comic and hints), and children-written narrative introduction and game rules.

2.5 PHASE 5: Development

The materials produced in phase 4 were passed on to the organizing association Blenio Bellissima, who took care of developing high-quality materials for setting up the actual ER following the children’s indications and drawings. Two elements were largely improved in this phase: the narrative introduction, that was expanded to also integrate the game rules and that was recorded into a video by professional actors; and the written summary of the game rules, that was completed and formatted with a word processor (Figure 5). Reboot instructions for the museum staff were produced.

The escape room was set up in the Casa dei Landfogti as planned (Figures 6 and 7), and a training session for the museum staff was organized, so that they would know how to introduce the ER to players, and how to reboot after each game.

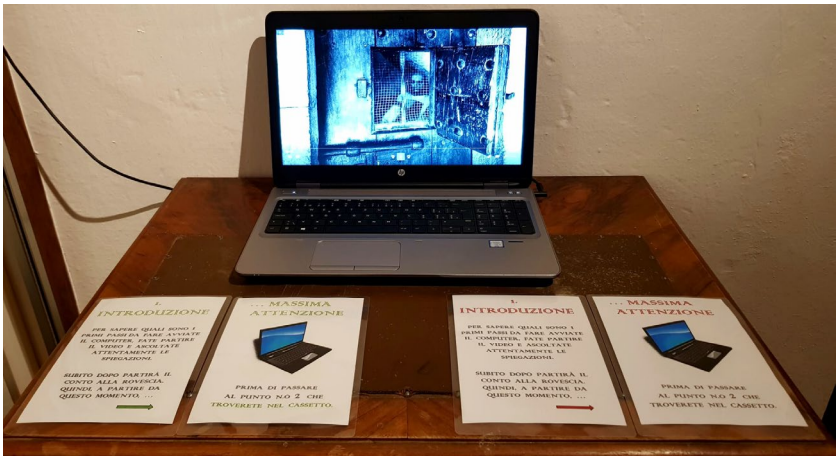

Figure 5: Introduction and rules station of the ER in the hallway

Figure 6: Some of the puzzles in the ER

Figure 7: A Part of the ER set-up in the first room

3. Outcomes

After its installation in the ancient local prison, the escape room enjoyed the visit of 125 teams (about 650 players) in 6 months (mind-June to mid-November 2022; the opening months of the museum), including tourists, local families, groups of friends, and 30 school classes, representing a successful example of open school game design project. The short and non-compulsory form of the museum collected extremely positive feedback, and many wondered at learning that the ER was designed by primary school kids. The large proportion of players, including school classes, that came to the ER by word-of-mouth also suggests that is was positively welcomed.

Of course, the pupils who designed the ER were extremely proud of their collective creation. During the debriefing at the end of the project week, they commented on having learned that some results – like the development of a complex game as an ER – could only be reached with the participation of everybody. Collaboration and awareness of its importance were definitely a positive learning achievement for this group.

The ER design project proved a motivating context for working on several disciplinary competences. Pupils had the opportunity to learn the key facts about Maestro Martino (which is part of their History program), to develop formal reasoning in puzzle design, to make a drawing of how the ER would look like, and to write different types of texts, including short hints, the rules, and the introductory narrative.

This project was also an opportunity to introduce game culture: children discovered that games are designed (and do not just "exist"), that some people design games as a job, and that games can be embedded into broader cultural initiatives. Most important of all, they engaged in designing a game geared for learning, and not just fun.

4. Conclusions

This paper presented a case study of educational escape room design with a primary school class as a project-based learning experience. The project was coordinated with a local organization embedded in the context of a regional cultural initiative. The previous sections outlined the design process, how school activities interacted with out-of-school and professional development phases, and the project outcomes.

As a case study, the findings of this paper cannot be generalized. Its focus was on a single experience that took place within a specific school (a small institute) and class (grade 3) context in a rural alpine region; it is fair to expect that the same approach in a different situation would require adjustments and possibly yield different results. From a methodological point of view, the case study was not accompanied by structured (quantitative) data collection and analysis.

Nonetheless, I believe it illustrates the power of educational ER design for learning under at least three respects.

First, it proves that even a complex game device as an ER can be designed with kids and suggests some scaffolding ideas to makes it manageable. For example, preparing a thorough requirement analysis in advance; clearly delimiting the knowledge items or learning goals to be included in the game; structuring group work; and using material constraints as elements to simplify design decisions.

Second, game design can foster open schools, or creating a bridge between educational institutions and local partners, including cultural associations (like Blenio Bellissima) and companies (like BlockaTI). We believe such interactions are an added values and a relational asset for schools. Moreover, children were engaged in designing an authentic product, and not an output for evaluation – which is fundamental for competence-oriented education. Indeed, the class teacher is already thinking about creating a new ER in collaboration with the local photographic archive.

Finally, this experience supports the claim that games can add value to cultural events. In this case, the escape room contributed to enhance the overall celebration of Maestro Martino, adding a perfectly integrated popular and fashionable element to the celebration, so that many young people and families learned about the cultural events in Valle di Blenio thanks to curiosity for the escape room.

Educational ER should be considered as all-round instructional devices, beyond their use as a specific and effective game-based learning approach. ER have the potential for generating meaningful game design experiences and connecting education and the community. These could be new avenues for research on educational ER to explore.

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Design Experiments in Game-Based Learning of Metacognition

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Abstract: Learner metacognition is one of the most influential factors that positively affects learning. Previous work shows that game-based learning can contribute to supporting and developing metacognitive knowledge and skills of learners. While there are many specific examples of such games, it remains unclear how to effectively design game-based learning environments to achieve this in an effective way. In other words: there is sufficient case-specific evidence, but limited design knowledge derived from such cases. In this paper, we attempt to identify such intermediary design knowledge that resides between specific games and generalized theory. We present three design experiments where game-based metacognitive training is evaluated in real-world educational settings. We collected insights regarding usefulness, motivation, usage, effort, and metacognition among participating students. From these experiments we identify what was learned in the form of design recommendations and, as such, contribute to collecting intermediary design knowledge for designing game-based metacognitive training.

Keywords: Game-Based Learning, Metacognition, Design experiments, Design research

1. Introduction

One of the most influential determinants of efficient and effective learning is metacognition: the knowledge a learner has about how they acquire new knowledge and the skills to use that knowledge to monitor and regulate learning (Brown, 1978; Flavell, 1976; Veenman, Van Hout-Wolters, & Afflerbach, 2006). However, metacognition is not equally developed in al learners and does not commonly develop autonomously (Veenman, Elshout and Busato, 1994; Veenman, Van Hout-Wolters and Afflerbach, 2006). Providing learners with metacognitive training seems an effective way of improving their current and future learning skills and, in turn, their learning performance.

Such metacognitive training must be *active* (to combine development of knowledge and skills with practice), *engaging* (to ensure learners exert the additional effort over a longer period of time) and *self-contained* (to allow learners to use an intervention regardless of the context and as they see fit). Game-Based Learning (GBL) could satisfy these practical needs. Indeed, various reviews of GBL have proposed to further investigate how metacognition can be impacted through GBL (Sitzmann, 2011; Ke, 2016; Hacker, 2017). However, current insights are limited to specific case-by-case findings and it remains unclear how to effectively design game-based learning environments (GBLEs) to achieve this in an effective way (Braad, Degens and IJsselsteijn, 2019, 2020). In other words: there is sufficient case-specific evidence, but only limited design knowledge derived from such cases.

In this paper, we attempt to identify such intermediary design knowledge that resides between specific games and generalized theory (Höök & Löwgren, 2012). We present a series of three design experiments. Each design experiment focuses on a particular prototype: a proposition of 'what could be' (i.e., a proposed design configuration). The role of this prototype is thus predominantly as a vehicle for inquiry and focused on quickly rejecting bad designs and thus increasing the likelihood of finding good ones (Binder & Redström, 2006; Bang & Eriksen, 2014; Easterday, Lewis and Gerber, 2014; Wensveen & Matthews, 2014). The prototype is evaluated in real-world educational settings to make inferences towards 'what should be' (i.e., a preferred design configuration) (Zimmerman & Forlizzi, 2008). The evaluations focus on (1) usefulness and motivation to use, (2) usage and perceived effort, and (3) metacognition and strategies.

Throughout the design experiments, we sample the design space with instantiations and from these experiments we identify and formalize what was learned in the form of design recommendations. As such, we contribute to collecting intermediary design knowledge for designing game-based metacognitive training.

2. Design Experiment #1

2.1 Design

This design experiment studies a GBLE that combines learning of metacognition with motivation through gameplay as two separate parts. The learning part uses the self-regulated learning cycle to encourage learners to reflect and adapt their learning process (Zimmerman & Campillo, 2003).

To allow use of the GBLE with any type and content of learning, the design of the GBLE makes no assumptions about what is being learned but, crucially, prompts learners to self-explicate learning goals, activities, and strategies and to evaluate these afterwards (Braad *et al.*, 2022). The GBLE does provide learning strategies adapted from Zimmerman & Schunk (1989), Schraw (1998), and Dunlosky *et al.*, (2013). Through engaging in the metacognitive activities, learners earn virtual currency in the form of gold, which can be spent in the gaming part of the GBLE to advance. As such, the GBLE rewards the effort a learner puts into metacognitive monitoring and regulation with an advantage in the game.

The gaming part is based on Space Invaders (Taito, 1978), where the player needs to defeat wave after wave of opponents by shooting at them. In the gaming part, virtual currency buys upgrades to increase winning odds and advance levels. The game unlocks learning strategies, which can be used for planning. As such, the game links progress in the gaming part to additional options in the learning part.

2.2 Evaluation

The study was conducted over one session with all participants present (8 students in higher education, 3 female, 5 male, aged 20-25 years). Participants were informed of the objectives and procedure of the study and received a 30-minute introduction explaining the relevant features of the GBLE. The participants then worked for 60 minutes with the GBLE as they saw fit. Finally, the participants took 15 minutes to complete a self-report questionnaire and participate in an interview.

2.3 Results

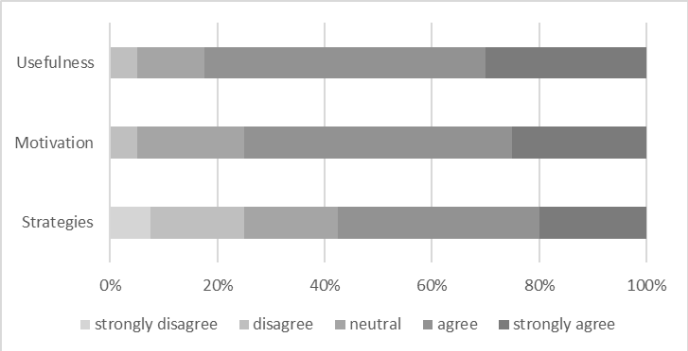

Figure 1: Participant perceptions of usefulness, motivation, and relevance of strategies offered through the GBLE

Usefulness and motivation

The results of the questionnaire are shown in Figure 1. More than half of the participants (strongly) agreed it was useful and multiple participants mentioned improved insight in estimating and planning time for learning:

> *"I learned that tasks take a lot longer than you expect. Planning specific time when to study is very useful."*
>
> *"Scheduling your time and finding out and using new or a variety of learning strategies can be useful and fun."*

While none of the participants strongly disagreed with the GBLE providing motivation, interviews revealed that some participants found the game too difficult to play. Suggestions for improving motivation included altering the game loop, making the game more visually appealing, and incorporating social features into the game. One participant found the gameplay mostly distracting from learning:

> *"I think it's a bit silly that you have to play a game before you can get new strategies. This disturbed my attention and distracted me".*

Metacognition and strategies

Regarding metacognition, on average participants were satisfied with the applicability of the provided learning strategies. However, some participants struggled to use the GBLE when the available strategies could not be meaningfully applied to current learning: "Not all learning strategies were applicable to what I was studying. I couldn't really implement one". Most participants reported becoming more aware of which strategies may be effective, however, only two participants said they had tried out a new strategy and only one participant agreed that they had found new ways to learn.

2.4 Conclusions

In conclusion, this GBLE design has some potential to motivate learners and affect metacognition. We learned that the extrinsic integration of metacognitive instruction with gameplay, in this design experiment, appears to be a two-edged sword: it may engage learners who would otherwise not perform metacognitive activities, but risks disengaging learners who otherwise would perform them. Participants suggested that, in addition to the individual approach, a social element could help to motivate learners. The training should also be more applicable to ongoing learning by providing relevant learning strategies. Overall, this design and evaluation warrant further research, as the suggested improvements of social features and more applicable strategies can be implemented with reasonable effort.

3. Design Experiment #2

3.1 Design

We further explore this design approach by addressing the suggested improvements and studying its use in a real-world learning context over a longer period of time. To address the need for a social element within the GBLE, we implemented a global leaderboard feature where learners could compare themselves to other learners in a competitive way. However, to avoid disengaging low achievers (cf. Ter Vrugte *et al.*, 2015), the incentive structure was designed to encourage trying out new and different learning strategies, rather than to encourage learning performance directly (cf. O'Rourke *et al.*, 2014). The position on the leaderboard was based on the number of different learning strategies used and, as such, provides a social incentive to try out different strategies. To address the need for more applicable strategies we added learning strategies specific to this group's writing assignment.

3.2 Evaluation

This experiment was conducted among a group of *N*=40 students (33 female, 5 male, and 2 unspecified), aged 19-29 (*M*=22.1, *SD*=1.9). To assess learners' perceptions of working with this GBLE, a similar self-report measure as in the previous design experiment was used to assess motivation, usefulness, use of learning strategies, and required effort. Quantitative log data from the GBLE were used to trace learner activities. The metacognitive awareness inventory (MAI; Schraw and Dennison, 1994) was used in the pre-test and post-test to measure participants' awareness of metacognitive knowledge and skills during learning. During the four-week period, a weekly lecture was scheduled, with the final hour designated for working with the GBLE. Students could use the GBLE as they saw fit during these sessions or at any other time.

3.3 Results

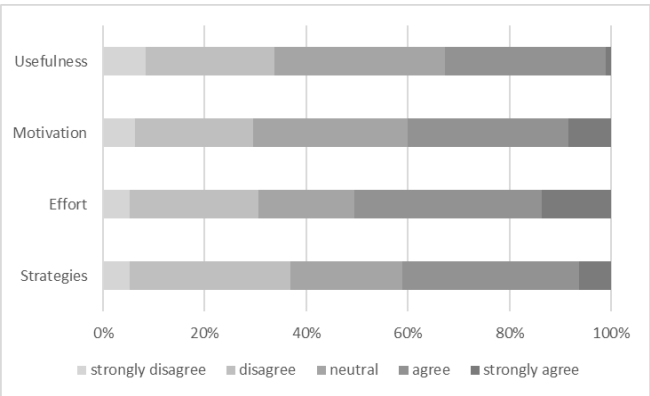

Figure 2: Participant perceptions of usefulness, motivation, required effort and relevance of strategies offered through the GBLE

Usefulness and motivation

Some participants found the GBLE useful for their own learning process, however, multiple participants indicated that the GBLE would be more useful for first year students:

> *"[It] provides a designated environment where you stay on top of your project."*
>
> *"I liked using the app to log my activities and see how much time I spent studying."*
>
> *"For people who do not yet have a clear idea of how to learn, it's probably very useful because it allows them to try out different strategies."*

Multiple participants found the game pretty fun and named playing the game and getting on the leader board as its best feature. In contrast, about the same number of participants found the gaming element frustrating:

> *"Time-consuming and not very useful for people who are not motivated by games"*

Usage and effort

On average, participants used the tool for up to 7.5 hours minutes (M=1.8, SD=2.0). Usage was spread over 1 to 10 distinct days (M=3.7, SD=2.7) and distributed over 1 to 28 sessions (M=8.0, SD=7.9). However, the gaming activities sometimes took more time than the actual studying effort itself:

> *"I spent way more time playing the game to earn new learning strategies than actually working on my essay. The game was fun, yes, but I feel like I wasted a lot of time on it."*

Metacognition

For some participants the GBLE helped to regard learning metacognitively, however, for multiple participants these insights were not new:

> *"It forced me to actively think about the ways in which I approach the assignment"*
>
> *"The strategies I did use were useful, but I was already aware of them and using them in my learning process."*
>
> *"It's not motivating to people like me who have established writing routines"*

Sometimes the provided strategies did not match the learning task:

> *"It is not that they were not useful, they just weren't useful for the part of the essay writing process that I was in at that moment."*

For the participants who completed both the pre-test and the post-test (N=12), a one-tailed paired-samples t-test indicated no significant increase in metacognitive awareness between pre-test and post-test, $t(12)=.640$, $p=.268$, $d=.185$.

3.4 Conclusion

The GBLE was generally considered to be of added value, in particular to organize learning into goals and activities, and to plan and time learning activities. Learners were now able to meaningfully apply the available strategies to their learning process. The extrinsic integration of learning and playing was received positively in general, even when a simple type of gameplay was used. However, the leaderboard that was introduced as a social incentive to increase motivation played only a limited role in motivation to use the GBLE. As in the previous design experiment, this design worked for the majority of learners, however, others viewed the game as an obligatory waste of time.

Measures of use of the GBLE, both in terms of frequency and duration, indicated participants did use the GBLE regularly and both in response to cues (during the sessions) and, to a lesser extent, in a self-initiated way (outside of class). This corroborates the results for usefulness and motivation of the GBLE.

We did not find a significant increase in metacognition. Some participants were encouraged to think about their approach to learning, and a few tried a different approach than before, but unfortunately without much satisfaction. Thus, while most participants could now meaningfully apply the provided strategies to their ongoing learning, this brought them few new insights. The use of this GBLE was mostly recommended for more novice learners, indicating a potential mismatch between the support offered by the system and the need for support as perceived by learners.

In conclusion, we learned that this GBLE design may have potential to motivate learners and affect metacognition, if the effort involved in both learning and in playing can be reduced, while at the same time motivation to use and keep using the GBLE can be improved.

4. Design Experiment #3

4.1 Design

The previous two design experiments showed potential for combining self-explication with GBL. However, we also found that use of such GBLEs is limited in duration as well as frequency, and use occurs mostly in response to external cues. Furthermore, we learned that not all learners are motivated by games and some regard the effort required for gaming activities as superfluous to learning. Therefore, in this final design experiment, we explore a design that promotes motivation to initiate and sustain use of the GBLE, while not demanding the effort of playing through a game as in the previous design experiments.

To support learners' metacognition throughout the SRL-phases of preparation, performance, and appraisal, four features were implemented: goals, methods, plans, and a logbook. Each feature included an open prompt to avoid providing too much or too little guidance. For example, the goals feature allowed leaners to specify their goals during learning via the prompt: "What are you trying to accomplish? Which objectives in learning do you have? Here, you can keep track of your goals." The methods feature allowed learners to specify the different ways of learning they use, while the plans feature enabled them to formulate relevant learning activities and link them to their goals and methods. The logbook feature allowed learners to record relevant occurrences during learning, with some events automatically added.

To incentivize use of the GBLE, we combined game design elements of varying complexity (Deterding *et al.*, 2011) to appeal to different forms of extrinsic and intrinsic motivation (Przybylski, Rigby and Ryan, 2010; Proulx, Romero and Arnab, 2017). Users could form groups, chat, and earn badges for completing activities within the GBLE. The badges were displayed in bronze, silver, and gold when unlocked and in black when not yet unlocked. Group members could view each other's badges and work together to collect them, fostering cooperation. The group's collective achievements were converted into a score displayed on a leaderboard. A dedicated forum allowed users to exchange insights, examples, and tips, as well as share their goals, methods, plans, or logbook entries for peer feedback.

4.2 Evaluation

The evaluation took place as a 9-week long in-vivo quasi-experiment, with students randomly assigned to either the intervention group using the GBLE or the comparison group not using the GBLE. The study adopted a within-subject pre-test/post-test design and mixed methods were used to collect data.

The study was conducted among 12 undergraduate 1st-year classes. Participants in nine randomly selected classes were assigned to the intervention group with N=39 students completing the experiment (26 male; 13 female; aged 16-26, M=19.4, SD=2.0). The comparison group consisted of N=15 students (9 male; 6 female; aged 18-28, M=20.1, SD=2.6).

The measures taken during this study were collected through a pre-test questionnaire, focus group sessions, log data from the GBLE, and a post-test questionnaire. The MAI was used to assess metacognition (Schraw & Dennison, 1994; Harrison & Vallin, 2018). A researcher introduced the study and metacognition in the first week and administered the pre-test questionnaire. Students used the GBLE for eight weeks, with weekly reminder emails. Two focus groups were organized in the second week and the post-test questionnaire was administered in the final week.

4.3 Results

Perceptions and motivation

The results from the participants who did use the GBLE indicate that they did not enjoy using it and found that using it involved too much effort. This could be partly due to limited guidance on how to use the GBLE:

> *"I did not understand at all what to write down at the method part, so maybe give examples."*

Some participants found that the goals-, methods-, and plans-features contributed positively to learning by providing structure and control:

> *"When there were a lot of deadlines and I felt overwhelmed, writing it all down helped"*

The results from the participants who did not use the GBLE indicate that motivation did not play an important role in their choice. Instead, required effort (too high) and perceived usefulness (too low) were important reasons to not make use of the GBLE. Some participants felt overwhelmed altogether:

"I was too busy with assignments and learning to use the tool as well"

A few participants did not find the GBLE useful for themselves. The game features implemented to promote use and sustained use of the GBLE did not convince participants to use it. However, the reason for not using the GBLE that was most often given was simply forgetting about it:

"There was no bigger motivation behind the tool. The achievements were not enough of a reward"

"I initially wasn't too interested in using the tool and eventually forgot about it"

Usage

We analyzed data for N=29 participants who used the GBLE according to the log data. On average, these participants used the tool for up to 125 minutes (M=17.5, SD=27.1). Usage was spread over 1 to 5 distinct days (M=1.3, SD=.1) and distributed over 1 to 5 sessions (M=1.8, SD=1.2), with the majority of participants using the GBLE only on a single day and in a single session. Only 5 groups were formed involving only 11 of the users. Use of the forums was limited to 11 posts and 6 replies among 8 of the users. Only a few of these interactions related to learning, while most were initial messages to see how this feature worked.

Metacognition

We conducted a mixed factorial ANCOVA with the experimental condition as a between-subjects factor and the pre-test metacognitive awareness scores as a covariate. No significant effect of the experimental condition itself was found while accounting for pre-test scores, $F(1,51)=.319$, $p=.575$, $\eta^2=.006$. One-tailed paired-sample t-tests were then conducted on the pre-test/post-test contrasts of metacognitive awareness per group. In the intervention group (N=39), metacognitive awareness significantly increased between pre-test and post-test, $t(38)=2.077$, $p=.023$. The increase in the comparison group (N=15) was not significant, $t(14)=1.607$, $p=.065$.

4.4 Conclusions

On average, use of the GBLE over the experimental period was very limited in frequency: most participants used it only a few times. Duration of use varied widely and up to two hours in total, however, was limited to a quarter of an hour on average. Social interaction in terms of group-forming or interactions via forums was also very limited. We found a substantial drop-out of participants during the study but could not explain this in terms of a priori metacognition or motivation. Altogether, we can conclude that a potentially positive effect of using the GBLE on metacognition was not achieved for most students. The limited use of the tool, in terms of frequency and duration, prevents any strong conclusions regarding its effects on metacognition.

Although we found no indications of problems with the explicit system prompts and otherwise high amount of learner control, it remains unclear whether learners were able to use the GBLE in a productive way. Perhaps additional instructions and scaffold could have worked towards learning how to use the GBLE in a step-by-step way. For example, the feature regarding methods of learning seemed more difficult to use productively, and perhaps offering a few pre-made learning strategies could have improved its use. Moreover, additional cues within the GBLE, but also within the classroom, may have helped learners to use the GBLE more regularly and more productively. Altogether, in the present study our limited cues were insufficient to initiate use of the GBLE, as were the mechanisms within the GBLE to sustain it.

5. Discussion

We will first provide our recommendations as identified across these design experiments. We will then conclude the paper with suggestions for future research.

5.1 Design Recommendations

We recommend the following when designing GBLEs for metacognitive training:

- Make metacognitive support as relevant as possible to ongoing domain-specific learning – for example by suggesting strategies that are specifically relevant for current learning goals and activities. When domain-specific learning content is also taught within the GBLE, embed metacognitive training within this content of the GBLE: this makes the transfer easier and makes the support more relevant.

- When adopting a domain-general approach make sure that additional support helps learners to make the far transfer from metacognitive training to real-world learning. The mechanisms to promote transfer of metacognition to learning should be explicit and should be presented apart from gameplay to emphasize their different role.
- Inform users explicitly, beforehand, about the purpose and potential benefit of using the GBLE as this increases interest as well as the potential of transfer of metacognition to learning. Explicitly address learning in terms of the goals, activities, and strategies it involves. This can also be done in a summary after an episode of gameplay.
- Explicitly instruct and encourage learners to make use of the available metacognitive support features within the GBLE. Implement support features that cue the use of the available support.
- Consider learners' experience with learning and vary explicit instruction and implicit support accordingly. Consider the amount of effort involved in student control of the metacognitive support. Avoid superfluous effort and hard thinking without discernable benefits.
- When integrating metacognition with gameplay, be careful about the balance between time spent on game activities and on learning activities. Relate the gameplay loop to learning activities to benefit motivation as well as learning.
- Incorporate social interactions within the GBLE as these can work to promote motivation as well as metacognition. Explain and point out the use of social interactions within the GBLE and how these contribute to learning to encourage learners to make use of these.
- Avoid competition between learners on indicators of learning or metacognition: such performance-based competition is likely to disengage all but the high-ranking learners. Instead, seek for indicators of effort, novelty, and exploration of learning.
- Choose a deliberate type of gameplay that avoids time pressure and promotes thinking and reflection – in particular when striving to integrate metacognition with the gameplay. This allows players to reflect on choices and speculate on alternative outcomes.
- Alternate between metacognitive activities and gameplay activities to allow learners to engage in these activities from a different cognitive stance.

5.2 Conclusions and Future Work

Research of domain-specific GBL recommends intrinsic integration of learning content with gameplay. However, our design experiments indicate that such intrinsic integration is not similarly effective when training metacognition through gameplay. Previous research discusses similar issues when integrating such reflective activities with gameplay (Sabourin *et al.*, 2013; Verpoorten *et al.*, 2014). Correspondingly, approaches that more explicitly differentiate between gameplay and reflection thereupon have been shown to be effective (Fiorella & Mayer, 2012; Castronovo, Van Meter and Messner, 2018). This leads us to wonder whether intrinsic integration of metacognitive training with gameplay is possible or even desirable. Due to their different focus of learner attention, a disconnection between learning and playing may be necessary to facilitate game-based metacognitive training.

As metacognition requires a learner to inspect and adjust their own learning, it may be useful to reflect this different focus of attention in the design of the GBLE. The complexity of integrating metacognitive support with gameplay is to combine the "doing" associated with experiential learning of GBL with the "thinking" associated with metacognition. The stance adopted when learning, playing, problem-solving, could be inherently different from the stance adopted when monitoring, strategizing and reflecting (Martinez-Garza & Clark, 2017). In this sense, metacognition is at odds with experiential learning and requires an extra step beyond the context of the game – "breaking the fourth wall", if you will – for real-world learning to be affected. We conjecture that learning may additionally involve a metacognitive stance (a state of mind aimed at optimizing learning itself).

Future research should focus on resolving the complexities of combining learning, gameplay, and metacognition. With combined effort, and taking advantage from our learnings, future design and future research may find more sophisticated ways of improving metacognition through GBL.

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Entrepreneurship and Game-Based Learning in Higher Education: A Systematic Review

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Abstract: Game based learning and entrepreneurship education are two topics that have been gaining attention in recent years. This is due to the importance of entrepreneurship for economic growth, employment, and innovation. As such, researchers have begun exploring how game-based learning may be used to foster entrepreneurial skills, both in students and young graduates. Entrepreneurship education has become increasingly important in higher education as it equips students with the skills necessary to become successful in the business world. Even though many entrepreneurship education programs still use traditional teaching methods, it is now known that game-based learning can be a very effective way to develop entrepreneurship competences. In addition, research has shown there may exist potential benefits beyond just improving entrepreneurial knowledge. In fact, studies suggest that playing certain types of games may improve problem solving abilities by teaching players how to break down complex problems into smaller component parts as well as helping them to develop better communication skills needed when working with others on projects or collaborations outside one's own venture. All these findings make it even more important for us to understand why people enjoy playing different kinds of games so that educators can create experiences that will not only help grow businesses and to develop entrepreneur's mindset in youngsters but also provide enjoyable experiences along the way too. This systematic review aims to examine the current literature on the use of game-based learning approaches in higher education to develop entrepreneurship competences.

Keywords: Entrepreneurship; Game-based learning; Higher Education

1. Introduction

As highlighted by Hessels & Naudé (2019) there is not yet consensus about the word entrepreneurship, although they propose a 'synthesis definition', according to which, entrepreneurship is "the resource, process and state of being, through which individuals with ability and agency utilize positive opportunities in the market for generating individual and/or social value" (Hessels & Naudé, 2019, p. 397). On the other hand, the definition adopted by the EntreComp, a framework for entrepreneurship education and training developed by the European Commission – originally proposed by the Danish Foundation for Entrepreneurship & Young Enterprise - is as follows: "entrepreneurship is when you act upon opportunities and ideas and transform them into value for others. The value that is created can be financial, cultural, or social" (Bacigalupo et al., 2016, p. 10).

Despite the lack of consensus about a definition of entrepreneurship, in today's global market, characterized by the reliance on knowledge, entrepreneurship is seen as essential for countries looking to remain competitive. This is because entrepreneurship is often associated with promoting economic growth, fostering creativity, and encouraging innovation. As a result, there has been a growing interest in creating educational programs that support and enhance entrepreneurial skills (Boldureanu et al., 2020). In fact, entrepreneurship is considered as a key skill of the 21st century, alongside other abilities that are necessary for achieving success in the knowledge society, such as learning and working (Antonaci et al., 2015).

Entrepreneurship Education (EE) has become an essential component of higher education as it contributes to equip students with the skills necessary to become successful in the business world, but it also provide graduates with the tools to approach their work in a dynamic, innovative, and adaptable manner (Tony, 2016). Entrepreneurship education is a process of teaching and learning about the knowledge, skills, values, and attitudes needed to start, manage, and grow a business. It includes recognizing opportunities, managing resources in the presence of risk, and building a business venture. It also involves developing entrepreneurial attitudes and skills, not just training for business start-ups. Additionally, it aims to develop enterprise capacity and prepare students to integrate the workforce with an entrepreneurial and innovative attitude. It is seen as an effective way to prepare graduates for the workforce by focusing on skill and competency development. Overall, entrepreneurship education is considered to be a key component in equipping students with the knowledge and skills needed to exploit opportunities in the current knowledge environment (Hynes and Richardson, 2007).

The increasing interest in EE has led to various objectives for the field, as well as a variety of pedagogical approaches used to deliver it (van Ewijk, Oikkonen and Belghiti-Mahut, 2020). The techniques and strategies employed in entrepreneurship education tend to vary widely across different programs, classes, and geographical regions (Neck and Corbett, 2018).

It is important to note that gamification and game-based learning are related concepts, but they are not the same thing (Kapp, 2012). Gamification refers to the use of game design elements and mechanics in non-game contexts, such as business, education, or health care, in order to engage and motivate people to achieve their goals (Hessels and Naudé, 2019). Game-based learning, on the other hand, refers to the use of games as a tool for teaching and learning (Hessels and Naudé, 2019).

Game-based learning has gained popularity as an effective approach in teaching entrepreneurship in higher education (Vandercruysse, Vandewaetere and Clarebout, 2012), since it is an interactive and engaging approach to teaching that utilizes games and simulations to provide students with hands-on experience in a simulated business environment (Nadolny and Halabi, 2016). This approach allows students to apply theoretical concepts in a realistic setting, which can make learning more meaningful and relevant. Game-based learning also promotes active learning, which is beneficial for students as it increases their participation and engagement in the learning process (Pesare et al., 2016).

Research has supported the idea that game-based learning is an effective approach to teach entrepreneurship. Studies have found that game-based learning improves students' ability to understand entrepreneurship concepts, increases their motivation to learn, and enhances their problem-solving skills. Additionally, game-based learning has been shown to improve students' attitudes towards entrepreneurship, which is important as a positive attitude towards entrepreneurship is associated with a greater likelihood of becoming an entrepreneur in the future (Carenys and Moya, 2016).

Despite the potential benefits of game-based learning, there are also limitations to this approach. One limitation is the cost of developing and implementing game-based learning programs (Whitton, 2012). Another limitation is that game-based learning may not be suitable for all students. Some students may not be comfortable with technology, if the games used are digital (Carenys and Moya, 2016), or may prefer traditional methods of learning (Greipl, Moeller and Ninaus, 2020). This systematic review aims to examine the current literature on the use of game-based learning in higher education to teach entrepreneurship.

2. Methodology

This study builds on a systematic review that aims to examine the existing literature on the relationship between entrepreneurship education and game-based learning in Higher Education. A comprehensive search was conducted in Scopus and Web of Science platforms, using keywords (within title, abstract and keywords of the documents) related to entrepreneurship education, game-based learning, and higher education. We used two databases, Web of Science and Scopus, that stand as the forefront citation databases, both globally acclaimed and engaged in fierce competition (Zhu and Liu, 2020). We applied some restrictions to our search: only articles and reviews were included, since they are peer-reviewed, which guarantees a greater degree of rigor when compared to other types of publications (Kelly, Sadeghieh and Adeli, 2014). The other restriction was on the language: only English documents were selected.

The number of documents per group of keywords, before and after the restrictions were applied is represented in table 1. The data was retrieved on the 14th of February of 2023. After removing the duplicates within each database, a total of 74 documents and 45 documents were retrieved from Scopus and Web of Science, respectively. These documents were retrieved to a single database, 33 duplicates were removed, leaving a total of 88 documents.

Table 1: Number of documents per group of keywords in the respective databases, before and after restrictions were applied. Scopus and Web of Science accessed on February 6, 2023. Source: own elaboration

Keywords	Scopus		Web of Science	
	Before restrictions	After restrictions	Before restrictions	After restrictions
Game based learning AND entrepreneurship	124	51	87	28

Keywords	Scopus		Web of Science	
	Before restrictions	After restrictions	Before restrictions	After restrictions
Gamification AND entrepreneurship	76	28	53	20

The titles and abstracts of the articles were screened for relevance. Eligible articles met the following criteria: (a) focused on entrepreneurship education and game-based learning in higher education, (b) had full-text available for review. A total of 28 documents were selected for full review. Although the search was not confined to a specific period, the oldest one was from 2009, highlighting the recent emergence of this topic in the scientific literature.

3. Results – Literature Review

Experiences with game-based approaches in entrepreneurship education

Serious games, which combine instruction and gameplay to create engaging learning contexts, have been recognized as potential effective tools for developing entrepreneurship and management competencies to university students. In a study by Bellotti et al. (2014), the authors conducted a comprehensive overview of serious games (SGs) available on the market and identified key benefits and issues concerning their adoption for teaching entrepreneurship. This approach may support "learning by doing", where students may practice and apply what they have learned in a hands-on way. Antonaci et al. (2015) propose a theoretical model that considers usability, pedagogy, and entrepreneurship skills expressed by state-of-the-art models to identify the most appropriate mix of serious games for use in entrepreneurship courses. This suggests that serious games may be carefully selected and integrated into entrepreneurship curricula to create engaging learning experiences.

Furthermore, gamified and collaborative courses for entrepreneurship education have been developed to help students become familiar with basic concepts of entrepreneurship and management and stimulate the emergence of their entrepreneurial attitudes. These courses incorporate game mechanics such as leaderboards and badges to enhance students' experience, engagement, and entrepreneurial self-efficacy. In a study conducted by Isabelle (2020), the course, with a 12-week format, involved the creation and operation of online ventures by 269 undergraduate students, who experienced the entire entrepreneurship process from ideation to launch of a real business and beyond. The findings suggests that gamification may be an effective approach to promote active learning and enhance students' entrepreneurial skills and attitudes.

In addition, simulation-based approaches have been used in entrepreneurship education to provide students with experiential learning opportunities. For example, a study by Arias-Aranda & Bustinza-Sánchez (2009) investigated the impact of a simulation experience on entrepreneurial attitude through conflict management learning. The study was conducted on a sample of 427 advanced undergraduate students majoring in Business Management and Administration, Economics, Tourism, and Marketing at the University of Granada (Spain). The selected simulation program, Praxis MMT v.10, tasked the students with managing a manufacturing company in the automotive industry. The study found that students who participated in the simulation experience scored significantly higher in conflict management handling modes that reinforce internal relationships within the team, such as collaboration and compromise, compared to non-participants. The simulation experience also positively affected personal control and self-esteem, improving the perception of control and conflict management approaches. The study concludes that incorporating simulation tools into educational programs related to entrepreneurship can improve conflict management capabilities and foster motivation and the development of cooperative attitudes.

Memar et al. (2021) investigates the effectiveness of gamification in large classroom settings for teaching causation and effectuation behaviors in entrepreneurship education, using an experiential learning exercise called the Strategic Business Game. The authors found that the Strategic Business Game prompts students' causation and effectuation behaviors, fosters better student interaction, and enhances the quality of learning. Aries et al. (2020), conducted a study in Entrepreneurship or Business Plan courses in BINUS online learning, a higher education institution in Indonesia that provides e-learning degree programs. The results obtained from a sample of 400 students indicate that gamification can positively influence attitude, perceived behavior control, and subjective norms, with perceived behavior control being the dominant factor, leading to increased entrepreneurial intentions among students.

Evidence on the impacts of game-based approaches in education

A study on the long-term effects of gaming simulation to teach entrepreneurship to German university students, particularly related to the business processes of startups, found that participants showed an overall increase in their knowledge of business administration and business plan preparation skills, as well as an increase in their desire to create a startup (Kriz and Auchter, 2016).

Likewise, the concept of flow experience, defined as a mental state of complete absorption in an activity, emerges in the literature related to game-based learning, in the context of entrepreneurship education. This concept is found to be critical in enhancing learning performance and entrepreneurial self-efficacy (Yen and Lin, 2022). The challenge-skill balance and playability of the game are identified as key antecedents of flow experience, and designing game-based learning environments that promote flow experience can lead to improved learning outcomes in the context of entrepreneurship education. This finding is supported by Grivokostopoulou et al. (2019), which demonstrates that gamified learning activities, particularly those implemented in 3D virtual reality environments, can significantly improve students' knowledge and skills in entrepreneurship, management, and finance, as well as increase their self-efficacy and intentions to engage in entrepreneurial activities.

Another important finding in the literature is the experiential nature of game-based learning. Williams (2015) focuses on SimVenture, a business simulation game, and demonstrates that it not only develops business and management skills but also entrepreneurial attitude and values in management students, highlighting the value of experiential learning through games in developing entrepreneurial skills and attitudes

Game-based learning has gained increasing attention as an innovative approach to teaching entrepreneurship and business management concepts in higher education. Several studies have explored the impact of various games on student engagement, skill development, and learning outcomes. For instance, the study by Beltrão & Barçante (2016) investigated the use of the "Industrial Administration Game" (JOGAI), which simulates a supply chain of jewelry production for export, covering the entire process from mining of raw materials to sale to the final exporter, to teach Business Excellence and Total Quality Management to undergraduate students. The findings indicated that the hands-on approach of the game was well-received by students and fostered entrepreneurship, increased class participation, teamwork awareness, and discussions on business ethics.

Yang et al. (2022) further examined the influence mechanism of virtual simulation game learning experience on student engagement and entrepreneurial skill development. The study found that game design, teamwork, and self-efficacy had significant effects on entrepreneurial skill development and learning engagement. This suggests that the design of the game and the collaborative nature of gameplay can influence student engagement and skill development in entrepreneurship education.

Rosli et al. (2019) investigated the use of a board game in teaching entrepreneurship and accounting to non-accounting students (N=49). Pre- and post-game experiment surveys found that game-based accounting education aids in generating an interesting teaching and learning environment on business accounting course that focuses on student-centered learning, and most of the respondents agreed that using games helped them to comprehend the business accounting knowledge better.

Moreover, the use of game-based learning approaches in teacher training programs has been explored as a way to enhance students' competences and provide better evaluation of outcomes. Canaleta et al. (2014) argue that traditional lecture-based approaches often result in student passivity, and active learning methodologies, including serious games and project-based learning, can promote pro-activity and improve the effectiveness of learning. The authors evaluate the results obtained in the Master in Teacher Training (MTT) program, which is a professional Master program for teachers who teach in Secondary Education, Baccalaureate and Vocational Training in Spain, in its first three academic years of implementation (2009-2010, 2010-2011 and 2011-2012). The authors also emphasize the need for a more profound use of Information and Communications Technology (ICT) to create a learning system adapted to the digital world that the new generations of students are integrated into. This suggests that game-based learning can be beneficial not only for entrepreneurship education but also for other domains, such as teacher training, to enhance student learning outcomes.

Insights about the importance of context for game-based learning

The social context of game-based learning is highlighted in several references. For example, Fonseca et al. (2012) describes a game that was designed as a Facebook application that guides users to develop a business idea in the form of a business plan allowing users to learn entrepreneurial skills in a social context. A consortium of

eight European partners from seven distinct countries (Portugal, Spain, Italy, Slovenia, Serbia, United Kingdom, and Belgium) developed the project, entitled "PLAYER-a". The authors of this study found that the social fabric of the game positively impacted the participants, increasing their propensity towards self-employment and the large volume of participants in the competition (N=2706) demonstrated a strong interest and demand for entrepreneurship education.

Similarly, Musteen et al. (2018) evaluate the effectiveness of the Global Board Game Project (GBGP), which aims to promote interactions between students in different countries. They collaborate online in a semi-structured manner to generate ideas, develop, and market a board game product to another country. The qualitative analysis of student essays indicated that the project was effective in helping students achieve learning outcomes, including defining, recognizing, and evaluating international business opportunities, designing and validating a business model based on such opportunities, and creating a plan for pursuing these opportunities.

Another common theme across the studies is the importance of motivation and engagement in game-based learning. Several studies (Mayer et al., 2014; Patricio, 2017; Kauppinen and Choudhary, 2021) show that motivation, personality traits, and previous gaming experience can significantly influence the perceived effects of entrepreneurship training. Mayer et al. (2014) focuses on the use of serious games in a Master's level entrepreneurship course at Delft University of Technology (TU Delft) in the Netherlands (N=27), finding that personality traits, motivation, and gaming experience can significantly influence the perceived effects on entrepreneurship after the training. The use of gamified tools, such as ideaChef® (Patricio, 2017) and Kahoot! (Kauppinen and Choudhary, 2021), is shown to enhance team engagement and participation in class activities.

The use of video games in developing innovation skills in the context of entrepreneurship and innovation education was also investigated. Tobar-Muñoz et al. (2020) conducted a study using the Innovator's DNA framework of skills and observed participants interacting with a game specifically tailored for fostering these skills. The study found that participants enacted actions involving observing, associating, and experimenting, which are skills related to innovation. On the other hand, Costin et al. (2019) and Manshoven & Gillabel (2021) highlight the benefits of using simulation games for enhancing entrepreneurial competencies and business model innovation. Costin et al. (2019) utilizes a simulation game called 'SimVenture' to investigate the development of cognitive and non-cognitive entrepreneurial competencies in a master's degree in international entrepreneurship at the University of Limerick, Ireland, emphasizing the transferability of these competencies to diverse business contexts. Manshoven & Gillabel (2021) presents the development and testing of a simulation board game called Risk&RACE aimed at bridging the gap between theory and business practice in implementing circular economy business models. The game was tested with 120 users, and results showed improved awareness, understanding, and insights in circular economy principles and business models. Players praised the engaging and realistic nature of the game, and debriefing discussions further deepened their learning experience.

Experiences with game-based approaches for students with different backgrounds

Several authors focused on the impact of teamwork and prior experience on student performance in business games (Alas et al., 2018; Almeida and Simões, 2019). Alas et al. (2018) discusses a study conducted in Estonia that explored the relationship between teams' characteristics and their performance in the business game Dynama, as well as the effect of market research information on their performance (N=713). In the game, students form teams representing the management of five competing companies in a business game. The authors concluded that success in the business game Dynama is influenced by factors such as acquiring adequate information (market research), quality of homework, and team discipline. Moreover, high academic achievement and prior work experience positively impact the achievement of a favorable result. On the other hand, Almeida & Simões (2019) highlighted the advantages and limitations of using serious games in entrepreneurship education, particularly for simulating challenges in start-up launch and management. Their study identified accessibility, interoperability, usability, and evaluation of student performance as global concerns in using serious games for entrepreneurship education.

The perception of students towards game-based entrepreneurship learning has also been explored. Ahsan & Faletehan (2021) conducted a qualitative study in Indonesia using the "Start and Improve Your Business (SIYB)" game. Data was collected from 441 participants through a nine-year survey. The authors found that participants liked the game for its positive impact on entrepreneurial spirit, skills, insights, and mindsets. However, some participants expressed concerns about the characteristics of the game, personal issues, and teamwork. This suggests that while game-based learning can have positive impacts, it is important to consider the concerns and preferences of students in the design and implementation of such games.

Other studies focused on the development of gamified software applications for business simulation and entrepreneurship learning. TIȚA et al. (2019) proposed the use of Unified Model Language (UML) and Business Process Model (BPM) tools to study business processes and develop a theoretical model for a gamified software application. The study aimed to provide a virtual simulation environment for understanding business principles in formal university education. Pratikto et al. (2021) explored the use of educational entrepreneurship game apps as a medium for online classes to improve students' analytical skills regarding business processes. The study found increased entrepreneurial analysis skills among students who engaged with the game-based mobile apps.

In addition to skill development, Zichella & Reichstein (2022) highlight the importance of entrepreneurship curricula that increase awareness of the cognitive mechanisms involved in biased decision-making with financial risk. Drawing on data from a money games experiment with undergraduate students (N=45), the article highlights specific biases relevant to high-risk environments, such as the prior gain effect and the degree-of-risk effect.

4. Conclusion

This literature review on game-based learning for entrepreneurship education in Higher Education Institutions reveals several key findings and trends. Overall, the studies highlight the positive impact of gamification on various aspects of entrepreneurship education, including entrepreneurial competencies, intentions, engagement, and innovation capabilities. The studies included in this systematic literature review suggest that game-based approaches may be effective in enhancing entrepreneurship education by improving students' innovation skills, changing perceptions of entrepreneurship and industry-related aspects, and increasing learning motivation and performance.

Although, many games primarily emphasize company management, with limited focus on fostering a specific entrepreneurial mindset, motivation, and skills such as innovation and the ability to identify and meet emerging needs of people. This gap is particularly relevant for technology students who need to be motivated and educated on starting a business based on new technology-supported ideas and products/services. However, the current market lacks complex "real-world" simulations that incorporate human factors, making it challenging to provide comprehensive training in this area. Furthermore, a notable limitation in many of the studies reviewed is the absence of a control group, which represents a significant shortcoming in the research design.

Overall, the literature indicates that games and simulations may be effective tools for teaching and enhancing entrepreneurial skills and attitudes in students. These tools may provide a social context for learning, allow students to face challenges, and develop their analytical skills and business knowledge.

One important direction for future research in entrepreneurship education is the examination of gender-related aspects within the learning environment. This could involve analyzing the behaviors and attitudes of individuals from different genders towards entrepreneurship activities and frameworks, with the goal of understanding potential differences and identifying areas for improvement. Additionally, future research could explore the efficiency of collaborative learning activities, where students work in teams and engage in cooperative learning, communication, and soft skill development. Further research can also explore the long-term effects of game-based learning on entrepreneurship outcomes, including evaluating the sustained impact of gamified interventions on students' entrepreneurial skills and behaviors beyond the immediate learning context.

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The Language of Life: A Game-Based Workshop for Introducing Protein Biosynthesis

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Abstract: Protein biosynthesis is a complex process that involves the transcription of DNA into mRNA and the subsequent translation of mRNA into proteins according to the genetic code. To introduce this fundamental process to a broad audience, we developed "The Language of Life", a game-based workshop that was presented at the Genoa Science Festival 2022, the largest science communication event in Italy. The game-based workshop employed jigsaw puzzle-like elements to represent DNA, mRNA, and aminoacyl transfer RNAs, enabling participants to pair them through codon combinations. The game-based workshop lasted for an hour and the framing was a "special mission" inside a cell. It consisted of an initial training phase that incorporated videos, models, and explanations, followed by practical "missions'' in which participants reproduce transcription and translation mechanisms by moving inside the cell and using the provided materials. The workshop was attended by 1,505 participants, primarily students aged 6-18, and received positive feedback. In this paper, we present our experience conducting this workshop and discuss its impact and potential for future use.

Keywords: Game-based learning, Genetic code, DNA, mRNA, protein, Transcription, Translation, Protein biosynthesis

1. Introduction

Motivation and participation are crucial elements of the learning process (Nesti 2017). Motivation refers to the drive or desire to engage in a particular activity or behavior, while participation involves actively contributing to the learning process, such as asking questions, participating in discussions, and engaging in hands-on activities. When students are motivated and actively participate in the learning process, they are more likely to achieve their learning goals.

Games can be a powerful tool for promoting motivation and engagement in learning activities (Nesti 2017, Yoon 2014, Whitton 2012, Annetta 2009). Games can provide a more collaborative and engaging classroom experience, especially for students struggling to stay focused. By incorporating gaming activities into education, instructors can mitigate learning anxiety while promoting student motivation to learn (Dorfner 2021).

Game-based learning has proven effective in STEM education. A few meta-analyses have been conducted, showing that digital games are a promising pedagogical method in STEM education (Wang 2022, Vu 2017). These studies have found that game-based learning has positive effects on cognition, motivation, and behavior (Arztmann 2023). However, further research is necessary to better understand when game-based learning is an appropriate approach and when it is not (Gao 2020).

While digital games hold promises and are increasingly popular tools, physical games have been shown to be effective in game-based educational programs (Bilancini 2023, Di Paolo 2023). We believe that more practical and playful activities can have a positive impact as well on STEM education (Sturges 2009, Chiarello 2016). Therefore, we conducted a survey during a workshop where game-based activities with jigsaw puzzle-like models were proposed to students with the purpose to engage students, fostering their interest, and imparting essential knowledge about DNA coding and protein biosynthesis.

The workshop was developed for the Genoa Science Festival 2022 (from October 20th to November 1st), which is the main Italian science communication festival, attracting about 200,000 visitors. The theme of this latest edition, “Languages”, inspired the title of this workshop, “The language of life”, and its main objective: to explain the protein biosynthesis process and the specific “language” involved, the genetic code, with a game-based learning approach. The workshop was designed to engage people of different ages, particularly primary, middle, and high school students, but also to accommodate the participation of older adults and parents with children.

2. "The Language of Life: Introducing Protein Biosynthesis"

DNA, or deoxyribonucleic acid, is a long molecule that, like a recipe book, contains the instructions (the *genetic code*) for making a specific protein in a cell. The genetic code uses four nucleotide bases - adenine (A), cytosine (C), guanine (G), and thymine (T) – in various ways to spell out three-letter nucleotide sequences called *codons*, each of which corresponds to a specific amino acid within a protein.

The protein biosynthesis process is how the cell converts genetic information contained in the DNA sequence (genes) into proteins. This multilayered process consists of two major steps. First, the genetic information is transferred to a *messenger RNA* (mRNA) through a process called *transcription*, where the DNA serves as a template for complementary base-pairing to generate a single-stranded copy of the gene. Then, the decoding of instructions for making proteins occurs during the *translation* step. The mRNA sequence is "read" according to the genetic code to assemble the chain of amino acids that form a protein (Alberts 2002). This process requires specialized RNAs called transport RNAs (tRNAs), which act as adaptor molecules between the mRNA and the protein. They have one end that can "read" the triplet code in the mRNA through complementary base-pairing and another that brings a specific amino acid.

3. "The Language of Life" Workshop

The workshop lasts one hour and is primarily designed for a single class (20-30 participants). However, it can also be adapted for a smaller number of players. The workshop is presented as a "mission" with the goal of helping a cell produce a protein, which in turn unlocks a series of locks. Various materials are used to support the activity, including four sets of genetic code elements: two complementary DNA long strips (coding and template DNAs), a series of messenger-RNA triplets (mRNA), and a series of similar triplets of transfer-RNA (tRNA) with associated amino acids (fig.1).

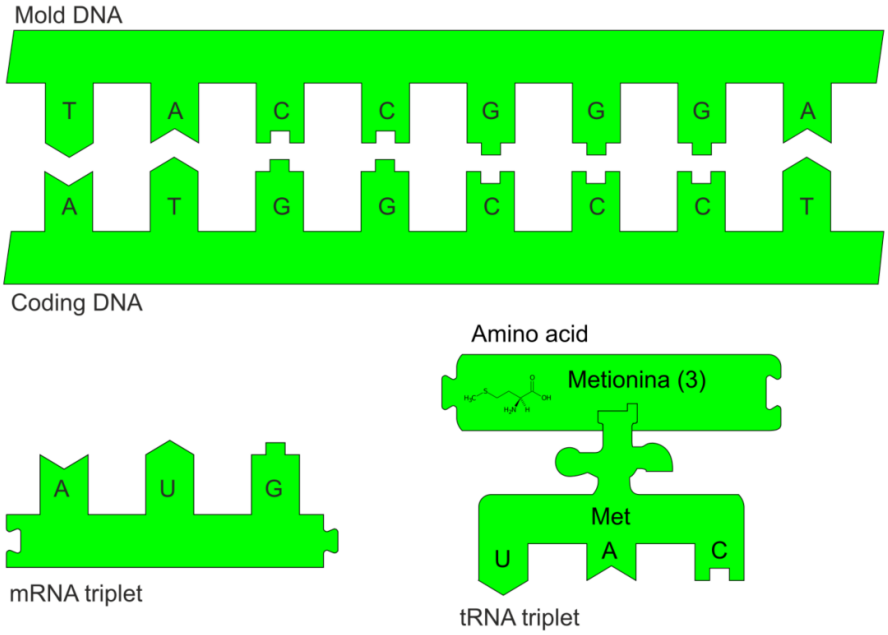

Figure 1: Scheme of the DNA and RNA elements: Template and Coding DNA strips (top), the mRNA triplet (left-bottom), and the tRNA triplet with its associated amino acid (right-bottom)

All these genetic code elements are created using Ethylene-vinyl acetate (EVA), which is a typical material for yoga mats. The EVA is cut into one-centimeter sheets using laser cutting technology, forming "backbones" with a series of "teeth" that terminate in interlockings, representing the four bases that can be coupled with complementary elements. Specifically, C is paired with G and A is paired with T or U (fig.1). The DNA consists of two long strips, while RNA triplets are separated and can be joined together using puzzle-type interlockings. Additionally, there are also four small wooden boxes that are closed by combination locks. The correct sequence of amino acids forming the protein must be determined to unlock the boxes (fig.2).

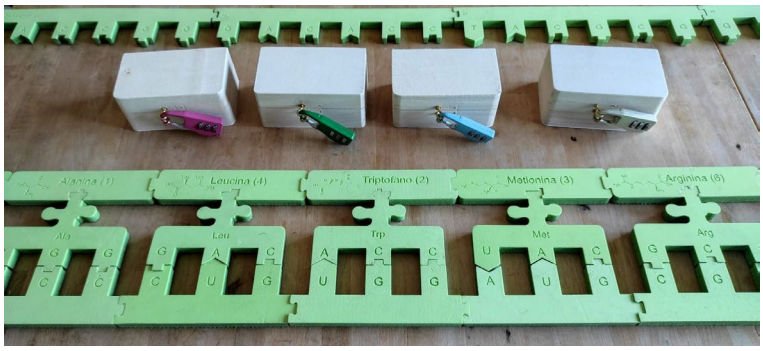

Figure 2: Photograph of DNA strips (top), boxes with locks (middle), and mRNA and tRNA triplets with their corresponding amino acids joined together (bottom)

In the first phase of the workshop, players are given training for their mission through a presentation and a series of videos (fig.3). Next, the first group is tasked with the "transcription" phase. They enter a designated "nucleus" zone in the room, separate the two DNA strips, and couple the complementary triplets of mRNA with the template DNA strip, thereby composing a copy of the DNA coding sequence. The composed strip of mRNA is then taken out of the nucleus zone and given to the second group of participants for the "translation" phase. The triplets of tRNA are paired with the complementary mRNA elements, and through this process, the single amino acids associated with the tRNA triplets are joined together to form the protein. Each amino acid has a corresponding number, and the correct order of these numbers is used as the combination required to open the locks, ultimately leading to the completion of the mission.

Figure 3: A moment of the workshop, during the training phase

After completing the workshop, there is a short debriefing session to summarize and reinforce the learned concepts, answer questions, and gather feedback on the impact of the experience. Two facilitators with university education in biology manage all of these activities.

During the Festival, there were approximately 70 workshops, and a total of 1,505 participants attended. Due to the fast-paced nature of the event and the large number of participants, it was challenging to conduct a comprehensive evaluation of the impact of the workshop in terms of raising awareness and promoting learning. Collecting accurate feedback data, conducting an analysis of the initial conditions, or ensuring long-term follow-up with participants proved to be practically impossible. Therefore, we conducted a short anonymous survey that only required basic information and a few self-evaluation questions. 1,045 responded to the survey. The gender distribution was 52.6% female, 43.0% male, and 4.4% not indicated. The main age was 16.8. Their age distribution is shown in fig.4.

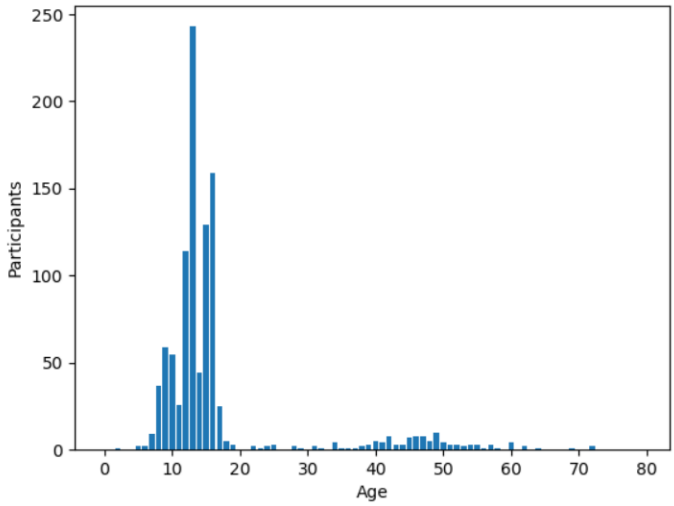

Figure 4: Age distribution of participants

The age distribution shows a significant peak in the range of school-aged children (6-18 years), which is likely related to the large number of visiting schools. There is also a smaller peak around 45 years, likely due to accompanying teachers. The main peak has three smaller sub-peaks around 9, 13 and 16 years, which may be linked to the time when students are studying genetics and related topics in their school curriculum. To evaluate the impact of the workshop, participants were asked to rate their experience on a 1-4 linear numeric scale (1 for "not at all", 2 for "not much", 3 for "a lot", 4 for "very much") on three main questions concerning interest raising ("Do you think your interest in these topics has grown thanks to this workshop?"), learning ("How much do you think you learned from this workshop?"), and appreciation ("Did you like this workshop?"). The summarized answers to these three questions are shown in fig.5, with a breakdown into four age groups: (A: 5-10 years, B: 11-13 years, C: 14-20 years, D: >20 years).

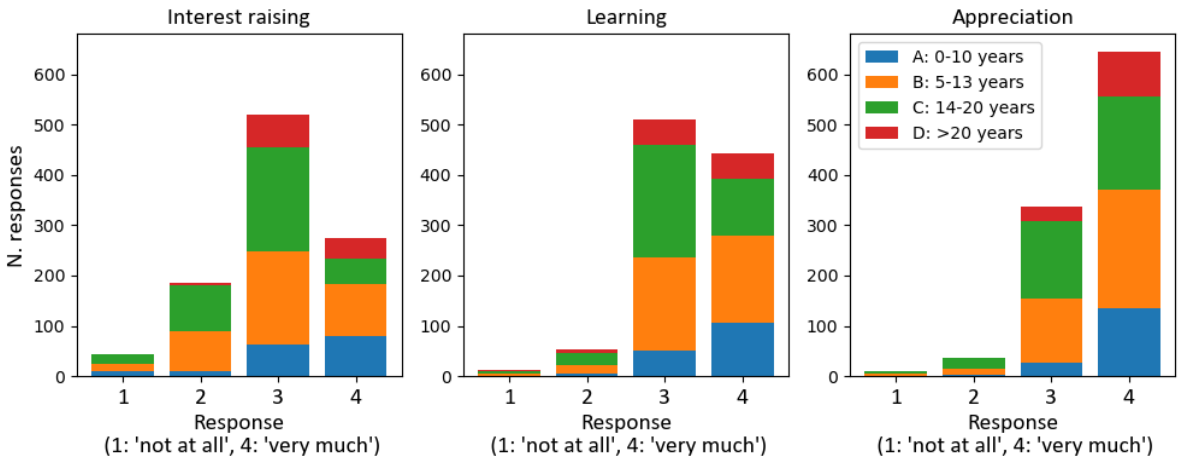

Figure 5: Histograms of the responses (disaggregated for age group) to the self-evaluation questions: "Do you think your interest in these topics has grown thanks to this workshop?" (left), "How much do you think you learned from this workshop?" (center), "Did you like this workshop?" (right)

In Table 1, we provide the mean values of the responses to the three questions, classified by distinct age groups. The results demonstrate a relatively balanced distribution for all three questions. Specifically, group B shows responses close to the overall average, while group C exhibits slightly lower scores, and groups A and D display slightly higher scores compared to the average.

Table 1: Mean values of the response to the self-evaluation questions for different age groups

	Interest raising	Learning	Appreciation
A: 5-10 years	3.31	3.60	3.78
B: 11-13 years	2.98	3.38	3.57
C: 14-20 years	2.78	3.21	3.42
D: >20 years	3.32	3.36	3.73
Overall	3.00	3.36	3.57

The results appear highly promising and suggest the effectiveness of this approach. However, further comprehensive studies are needed.

4. Conclusions

Game-based workshops can be a highly effective form of game-based learning, particularly suitable for younger students. Using games to teach and reinforce key concepts and skills can create a more engaging and memorable learning experience. Games can also provide a safe and low-risk environment for participants to experiment, try new things, and make mistakes without fear of failure. Moreover, games can be tailored to individual participants' abilities and preferences, providing a more personalized and effective learning experience. Ultimately, the use of game-based workshops can lead to improved knowledge retention, better collaboration and communication among participants, and improved performance outcomes. Therefore, organizations looking to enhance their training and development efforts may benefit from incorporating game-based workshops into their learning programs.

During the Genoa Science Festival 2022, we conducted a game-based workshop where 1,505 participants, primarily students aged 6-18, practically experienced DNA coding by combining jigsaw puzzle-like models. The data collected through questionnaires administered at the end of the workshop indicates that the experience had a positive impact on the participants, in terms of increased interest, understanding, and appreciation. However, further studies with an experimental design in a more controlled setting are needed to confirm the efficacy of game-based workshops as a useful tool for STEM education.

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Applying Design Research for Cross-Disciplinary Collaboration: Experiences From a Gamification Process

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Abstract: This study explores applying design science research (DSR) frameworks to facilitate cross-disciplinary collaboration towards game development. It uses a DSR framework proposed by Peffers et al (2014) to integrate the knowledge and experiences of a cross-disciplinary research team and develop a game which gamifies the investment decision-making process of energy communities. The framework employed for this paper constituted five phases around problem identification, definition of solution objectives, artefact design and development, demonstration and evaluation. The iterative process of the framework allowed for gradual but incremental improvement in the outcome and the associated artefacts and sustained researcher collaboration. The resultant interactive in-person game required the participants (or their teams) to navigate through the complexities of the decision-making process in a community while considering factors such as information asymmetry, uncertain return on investments, time constraints, etc. The game was instantiated twice and was able to engage players effectively. Moreover, the post-game evaluation indicated that the players acquired learning about energy communities. The participants developed an understanding of the game only gradually and their engagement in the later rounds of the game. Three distinct investment strategies emerged from the two instantiations (diversification, focus on centralised options, or focus on decentralised options). The participants preferred to maintain a strategy rather than reacting situationally. This gamification experience, albeit applicable to this specific research context, shows that DSR frameworks can be successfully applied to facilitate cross-disciplinary collaboration because they allow for more flexible and iterative knowledge exchange. The post-game evaluation helped identify avenues for further improvements, such as focusing on incremental-iterative development of the output, expanding the flexibility and visibility of the game, involving a more balanced research team, etc. The contribution of this study lies in extending the discourse on cross-disciplinary collaboration by incorporating DSR frameworks and demonstrating the application of game-based learning beyond end-user application.

Keywords: Energy transition, Stakeholder engagement, Gamification, Design science research, Energy communities, Cross-disciplinary collaboration

1. Introduction

The grand challenges associated with the ongoing energy transition from fossil fuels to renewable energy sources require cross-disciplinary research and effective stakeholder engagement to develop innovative policies and solutions and facilitate behavioural change. Game-based learning is increasingly used to engage and educate various stakeholders associated with this transition (Wagner & Gałuszka, 2020; Gugerell & Zuidema, 2017).

This paper presents a game that gamifies energy communities' investment decision-making process. Energy communities are community-based organizations that promote local production and consumption of renewable energy by engaging their members. However, they face several challenges, such as eliciting member participation, enabling democratic decision-making and equitable distribution of benefits (Caramizaru and Uihlein, 2020). This game allows its players to understand the inherent complexities associated with the working of energy communities and those related to the uptake of renewable energy solutions. Additionally, stakeholders unfamiliar with the concept can learn about the bottom-up approach for accelerating energy transition and reflect upon their positions about energy communities. Further, energy community members can play this game to enhance their knowledge, system awareness and community decision-making skills. Moreover, researchers can use the game to observe interactions within and across a group of stakeholders and gain insights into their behaviour.

Although there are ample benefits for both researchers and the stakeholders involved in game-based engagement, there is a need to learn more about effective strategies to develop such games, particularly in cross-disciplinary research contexts. The complexity is often amplified due to limited resources (e.g., time and relevant expert availability) and diverse requirements (such as researchers' heterogeneous modes of observing and understanding human behaviour) needed for gamification.

This paper attempts to understand the complex process of game development in a cross-disciplinary setting. It reflects on the experiences and outcomes of a collaborative game development activity involving four researchers from a cross-disciplinary research team who develop a game around the investment decision-making process of energy communities. The activity was conducted in a self-organized way using a framework from Design Science Research (DSR) to iteratively and collectively integrate and assimilate the knowledge and experiences of the researchers into a game. The study shows how design processes can be harnessed to facilitate better outcomes by examining effective approaches, communication methods and collaboration techniques.

The rest of the paper is structured as follows: Section 2 presents the relevant theoretical background, Section 3 discusses the DSR framework applied in this work, Section 4 presents the outcome of the process (the game), and Section 5 reflects on the experiences of the researchers.

2. Theoretical Background

Game-based learning (GBL), gamification and serious games are often used interchangeably in the scientific literature, so distinguishing between the terms is often challenging. While scientists such as Keogh et al (2023) and de Almeida Souza et al (2017) have provided definitions and typologies for these terms, this paper follows the definitions supplied by van Gaalen et al (2021). They define "game-based learning" as an umbrella concept which includes both gamification and serious games. Gamification involves using game elements in non-gaming contexts, while serious games focus on using games to educate stakeholders or the game players. Thus, the final output of this paper can be characterised as a game which gamifies the investment decision-making process of energy communities.

Section 2.1 presents some examples of gamification in the context of energy transition, and Section 2.2 discusses the importance of design science research in collaborative game development.

2.1 Gamification in the Context of Energy Transition

Gamification has emerged as a promising approach to engage various stakeholders and enhance their understanding of the salient features of the ongoing energy transition to address climate change. One such application has been to nudge the energy consumption behaviour in the building and industrial sectors towards sustainable practices through real-time feedback and rewards (Ciabattoni et al, 2022), by employing principles of psychology (Koroleva et al, 2019), or through simulation games of city-wide energy systems (Bauer et al, 2022). Gamification has also been used to educate stakeholders about the operational aspects of solar energy (Hettinga et al, 2021), conflicting perspectives and interests in techno-economic and political decision-making (Schuldt et al, 2018), occupational health and safety issues of photovoltaic systems (Erten, Oral and Yakut, 2022), energy trading (Veeningen and Szirbik, 2018), and collaborative decision-making (Ștefan et al, 2019). Further, it has also been applied in non-educational contexts to facilitate communication across a heterogenous mix of stakeholders to encourage more streamlined policymaking and planning activities (Gissi and Garramone, 2018; Ouariachi and Elving, 2020). Moreover, gamification has also been used to elicit the public perception of issues around digital platforms for electricity trading (Smale and Kloppenburg, 2020), geospatial position of power systems (Steinberger, Minder and Trutnevyte, 2020) and policies like carbon tax (Suzuki and Ishiwata, 2022).

2.2 The Application of Design Science Research in Collaborative Game Development

This paper brings together four researchers from different backgrounds who collaborated to gamify the investment decision-making process of energy communities. Such collaborative research is challenging primarily due to the intricate process of integrating knowledge from a heterogeneous group of researchers (Lang et al, 2012; Gaziulusoy et al, 2016). Recognising the ensuing complexity is essential to enhance collaboration and knowledge exchange amongst the group members and with the stakeholders and ultimately produce a high-quality output.

The tenets of Design Science Research (DSR) can be especially pertinent in such co-development activities as they provide a systematic and iterative approach to designing and refining gamification activities tailored to the unique needs of collaborative research. DSR is rooted in the thought that knowledge can be gained by creating innovative artefacts (such as design frameworks, models or systems) which try to address a specific problem or challenge and focuses on developing and evaluating such artefacts (de Sordi, 2021). DSR has primarily been applied in information system design and innovation to bridge the gap between theory and practice by creating practical solutions and advancing knowledge in various domains (Wieringa, 2014). Integrating knowledge from multiple disciplines with DSR can help develop gamified systems that can effectively support cross-disciplinary research outcomes, foster innovation, and help address complex societal challenges. Figure 1 shows the concept

of DSR as applied to this paper. By embracing the complexity and integrating knowledge from multiple disciplines within the framework of DSR, gamified systems that effectively support cross-disciplinary research outcomes can be developed, thereby fostering innovation and addressing complex societal challenges. The following section explains the DSR framework implemented in this paper.

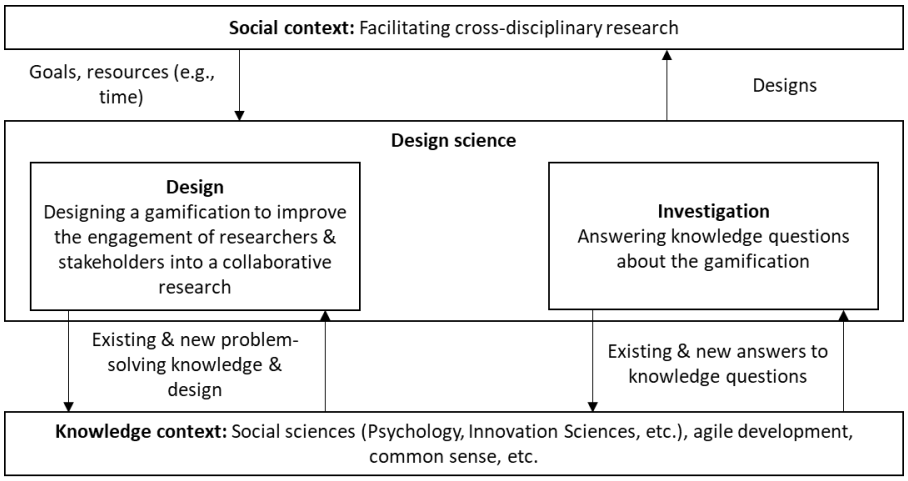

Figure 1: Schematic representation of the utilisation of DSR for this paper to facilitate collaborative development, adapted from Wieringa (2014)

3. Design Process

The game developers (the authors of this paper) applied a DSR process adapted from Peffers et al (2014) as a guiding framework (figure 2). This process consists of five phases, namely, (1) problem identification and motivation, (2) definition of solution objectives, (3) artefact design and development, (4) demonstration and (5) evaluation.

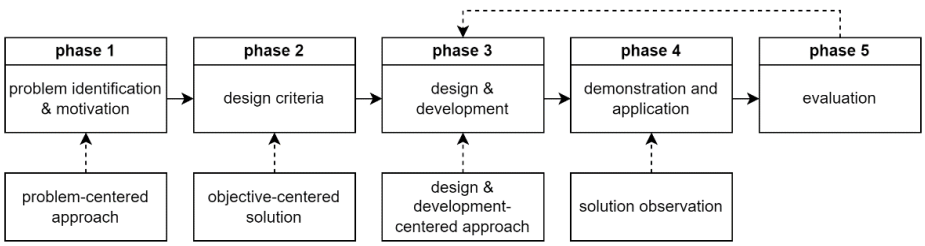

Figure 2: Outline of the study's design procedure, adapted from Peffers et al (2014)

The first phase aimed to identify the problems the design process should address, primarily through brainstorming sessions to leverage researchers' prior experiences. This phase dealt with two issues typical of cross-disciplinary research: (a) engaging diverse stakeholders for knowledge dissemination and (b) integrating knowledge from multiple disciplines to create a somewhat realistic environment wherein the researchers can observe the players' behaviour in a group setting. Since the authors shared a common pool of stakeholders, engaging each separately for each researcher's purposes would be inefficient. Hence, a design that allowed combined data extraction, useful for at least two researchers, was deemed necessary for stakeholder engagement. Moreover, the idea of knowledge integration necessitated that the design enables the stakeholders to actively take on a different perspective and share their views with other stakeholders.

Table 1: Objectives and corresponding design requirements for stakeholders

Objective	Requirement
Motivation	Stakeholder participation is voluntary; hence the session should appear interesting, relevant, and engaging enough to provoke participation.
Engagement	The session should involve elements that make the participants cognitively, behaviourally, and affectively commit to the session. The session should compel stakeholders to take on an unfamiliar perspective.

Objective	Requirement
	Stakeholders should have the opportunity to share their outlooks and thought processes.
Learning	The session should teach participants something about energy community and renewable energy diffusion by forcing them to adopt a system's perspective, future-based thinking through scenarios, design thinking (role-playing), proactivity (lock-in), and awareness (problem, system, and self).

Table 2: Objectives and corresponding design requirements for the game development team

Objective	Requirement
Motivation	Given the process's voluntary basis, the design process should be engaging enough and of limited intensity (not to interfere with other research activities) to sustain collaboration.
Engagement	
Learning	Research topics (content): observations related to the energy transition (perception, ways to deal with their problems, the crucial problems from stakeholder versus researcher perspectives and assumptions) Social learning (behaviour): observations about the stakeholders' behavioural processes and their approach to solving transition-related problems. There should be enough behavioural freedom to observe (unexpected) behaviour.

The second phase focused on deducing the design requirements based on the output of the first phase. These requirements for the stakeholders and the development team are listed in Tables 1 and 2. Other design criteria based on practical needs necessitated that the game should be developed within four weeks and should be playable within one hour.

The third phase involved operationalising the design requirements determined in Phase 2 into game elements (figure 3). This process generated the artefacts associated with the game, such as game set-up, equipment (game board, coins, etc.), and instantiation. The game thus developed is explained in section 4.1.

The fourth phase focused on demonstrating the game developed through the first three phases by inviting players to participate. The objective of the game developers in this phase was to conduct the game seamlessly while simultaneously observing and recording the interactions between the participants. Section 4.2 elaborates on the instantiation of this game.

The final phase focused on evaluating the experience of the participants and the game developers. The former was done through surveys and informal discussions with the players, while the latter involved reflections by the game developers. These outputs were also compared to the requirements listed in Tables 1 and 2 above to check the extent to which they were realised.

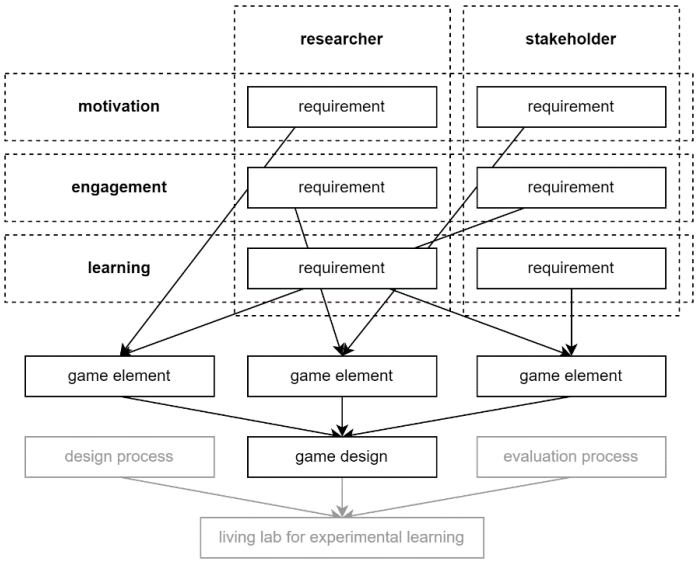

Figure 3: Diagram reflecting the evolution from game requirements to design

4. Gamified Investment Decisions in an Energy Community

This section presents the game that resulted from implementing the abovementioned DSR approach. Section 4.1 describes the game, section 4.2 elaborates on the testing environment, and section 4.3 reflects on the feedback received from the participants.

4.1 Description of the Game

The game required the participants to adopt the perspective of an energy community and provide the observant (the game developers) with insights into their investment behaviour. The participants were divided into groups and challenged to develop the largest energy community by making investment decisions across three rounds. They had three investment options to choose from- (a) increase the number of participants in their community, (b) invest in biomass-based energy projects, and (c) invest in installing roof-top solar with battery storage. Additionally, the teams also had the option to save their capital in a given round and use it in a later round. Each group received an initial endowment at the beginning of the game, which it could invest in one or more options. Each investment option was associated with a return on investment which determined the amount of capital they would have at their disposal in the next round. All the participants had access to the expected return on investment (ROI) associated with each option as well as potentially relevant new information in the form of news headlines, which may (or may not) affect the *actual* ROI. The teams had to process this information and make their investment within a time limit of two minutes per round. At the end of the three rounds, the team with the highest installed capacity won the game (figure 4).

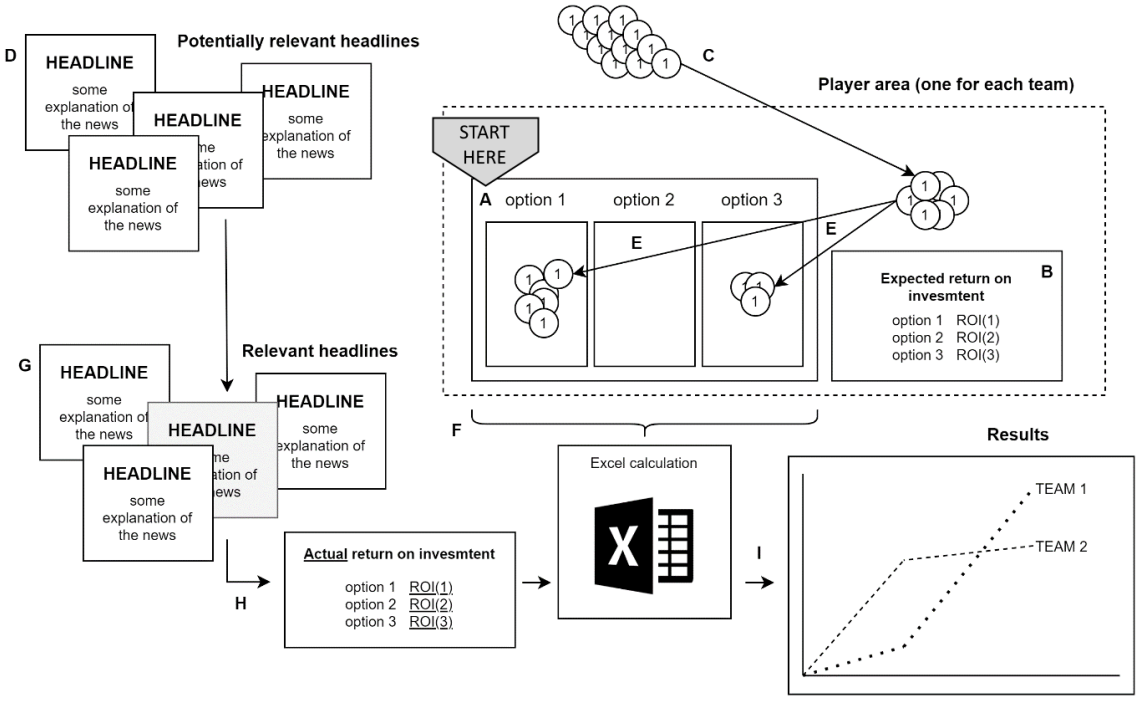

Figure 4: Schematic representation of the DSR instantiation. At the beginning of the game, each team was provided with an investment playboard with three investment decisions (A) and the expected ROI of these decisions (B). The first round commenced with distributing an equal number of coins to the teams (C). Next, the teams received a set of news headlines that could affect the actual ROI (D). The teams discussed the available information internally and made their investment decision by placing the coins on the playboard (E). After the decision window of two minutes was closed, the observers collected the results in the Excel worksheet (F) and the analyst performed the relevant calculations while the narrator explained the relevant news items (G) and how they affected the ROI (H). Each round concluded by displaying the outcome of the decisions made by the teams considering the actual or realised ROI (I).

This game design simulated several features associated with a typical decision-making process around energy investments. These features include information asymmetry (the players did not know which news items could affect ROI), uncertainty about ROI (to what extent the relevant news item affects the expected ROI), time constraints (the players had limited time to process all the information and arrive at their investment decisions),

and technological lock-in (it was attractive to keep investing in the same option across the three rounds). Such a design allowed the players to experience the complex and dilemmatic decision-making process as part of a group and evaluate trade-offs often inherent to energy investment decisions (such as risk versus safety, sustainability versus stability, staying with one investment option or altering across rounds). Moreover, this design allowed the game organisers to translate the investment behaviour of the players into measurable indicators and analyse it.

4.2 Instantiation and Testing

The game was first tested in an hour-long workshop with eight voluntary participants (i.e., four teams of 2), all closely associated with the field of energy transition (figure 5). The workshop occurred in October 2022 as part of an energy and mobility conference in the Netherlands. This session was supported by two observers (who collected information from the teams after each round), a narrator (who explained the features of the game) and an analyst (who performed the calculations). During this session, observations from the game development team only were recorded. However, a second instantiation of the game with players of similar characteristics was complemented with a post-game survey. Learning from both these sessions is included in the next section.

Figure 5: The DSR instantiation

4.3 Evaluation

The first instantiation of the game was evaluated through an informal discussion about the general experience of the participants. The second instantiation, however, was complemented with a survey consisting of sixteen questions. This survey was based on earlier works evaluating similar games, such as Ibanez, Di-Serio and Delgado-Kloos (2014) and Alfaqiri, Noor and Ashaari (2020). The survey results showed that the participants acknowledged learning about energy communities, thereby confirming the realisation of stakeholder learning objectives (table 2). In addition, the participants provided several other feedbacks which could be integrated into the subsequent iterations of the game, such as the inclusion of a socio-technical perspective instead of only a technocratic perspective as apparent in the current set-up, increasing uncertainty in the game to allow the emergence of newer behaviour patterns, and allowing more time per round to improve participant engagements and stimulate creative thinking.

The outcome of the evaluation conforms with the observations of the game developers. The participants were observed to develop an understanding of the situation gradually- while they were uncertain about their roles in the initial round, they enthusiastically developed their investment strategies in the subsequent rounds, mainly due to the rivalry between the teams. Three distinct investment strategies emerged from the two instantiations viz diversified investment (spreading investment across all three options), focus on decentralised option (investing in increasing the size and the generative capacity of the community), and focus on centralised options (biomass). Further, the participants maintained the same strategy across the three rounds of the game, confirming the game's technological lock-in character.

5. Reflection

This paper presents an application of a DSR framework in a cross-disciplinary research setting towards the co-development of a game which focuses on educating the stakeholders about a complex societal challenge associated with the ongoing energy transition. The game development process brought together four researchers from different scientific and cultural backgrounds who integrated their knowledge and experiences to develop a game that gamifies the investment decision-making process of energy communities. The game was instantiated twice with similar groups of players and complemented with formal (through a post-game survey) and informal (through a general discussion) discussions to capture the players' experience.

The DSR framework used in the game design process was adopted from the work of Peffers et al (2014) and was implemented in a self-organised way. This framework proved valuable for game developers who came from different backgrounds and had limited exposure to gamification and games. It helped overcome the challenges arising from the group's heterogeneity, making the collaboration feasible and viable. The iterative process of the framework incorporated in the design sessions, complemented with collaborative inputs and reflection points, ensured a gradual improvement of the outcome and the associated artefacts and sustained researcher engagement. Additionally, this approach allowed for flexibility and integration of new requirements as they emerged. It shall prove valuable in future game iterations to incorporate participant suggestions, such as including socio-technical perspectives, nudging group behaviour in a specific direction, etc. However, given the time constraint during the game's development process, the authors implemented the framework intrinsically to create a tangible outcome which prevented them from capitalising on the full potential of the framework. Further research is needed to understand the applicability of this DSR framework by applying it more systematically and rigorously in other collaborative research groups.

A retrospective analysis by the authors followed the game instantiation and testing to reflect on the decisions made throughout the collaborative design process and develop insights for the next iteration of the game. The retrospective was conducted using an agile approach, which is generally efficient for a small development team (Lindvall et al, 2004). This agile approach followed the typical phases of a retrospective, as indicated by Mas et al (2018). The retrospective, which included a review of the game, the game development process and the results, started with a brainstorming session to collect the topics for discussion and reflection. This discussion continued using a sailboat metaphor to identify the enablers, anchors and risks associated with the design journey (Table 3). The next step of the retrospective was to generate insights from the information collected so far. This involved categorisation of the enables, anchors and risks into high, medium and low priority with the idea that high-priority items would need to be addressed immediately and perhaps using a new approach, medium-priority items can be addressed during the subsequent iteration and possibly without necessitating a new approach. In contrast, the low-priority items need not be addressed. This retrospective process resulted in four key outcomes that should be included in the next iteration of the game: (a) improving the agility of the design process and focusing on iterative-incremental development by increasing the number of design iterations, (b) focusing on ideas to expand the flexibility and visibility of the game instead of adding more details, (c) forming a (more) balanced team with members from other (social science) disciplines, and (d) retaining the form of design research while ensuring that the process is more "fun" and less mechanical.

The game development process was primarily governed by selecting specific game characteristics based on the requirements envisaged during the first two phases of the design process. These requirements were based on the objectives associated with motivation, learning and engagement for both the stakeholders and the game developers. This offered a structured approach to effectively and strategically engage stakeholders and the researchers. In addition, the case demonstrates that game elements such as information asymmetry, time constraint, uncertainty, competition and team-based engagement fulfilled the objectives of the game developers to provide an enriching experience to the participants. However, as stated above, this was done somewhat intrinsically. Establishing guidelines linking specific game characteristics to observe, quantify and analyse typical participant behaviour shall significantly enhance the process. Accordingly, further research may be needed to verify if establishing such guidelines enhance the process's efficiency and improve the outcome's accuracy.

Table 3: Lessons learned from the gamification process

Enablers	Anchors	Risks
Openness to change – trust, tolerance, and mutual respect within the research team	Unknown aspects of the demonstration, such as the number of participants	Lack of diversity in stakeholder participation
Developing game prototypes early on in the design process	Conflicting schedules of the research team	Sustaining the collaboration
An attitude of converting threats to opportunities: Using time constraint as a gamification element	Time constraints in the design process and demonstration	Different design objectives of the game developers: game as a collaboration medium vs game as a laboratory

Finally, it is essential to note that the observations and conclusions drawn from this study are specific to its research context, wherein all the game players catered to a single demographic. Moreover, narrow stakeholder participation simplified the process but limited the artefact to meeting research criteria and perceived stakeholder demands. Further research is needed to assess if involving a more diverse selection of stakeholders would impact the effectiveness of the process and yield different results.

Acknowledgements

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A Simulation Game for Anti-Money Laundering (AML) Using Unity

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Abstract: With increasing demand of anti-money laundering (AML) regulation in Fintech, AML is one of the key factors in FinTech and its regulatory technologies (RegTech). Presently, as research and education on AML focus on financial institutions and authority, the individual is vulnerable to money laundering (ML) by being money mules with lack of awareness. Therefore, this paper illustrates the design of a 2-player simulation game for AML, which integrates the game-based learning model with plots including introduction stories, player actions and ending stories. In the game, a player role-plays either a money launderer or AML specialist. Within 6 in-game months, the former needs to perform ML with a target goal while the latter needs to identify the former's actions and restrict him to achieve his goal. For actions of the money launderer, this paper integrates the criminal order with the PLI model (placement, layering and integration) to simulate the full ML circle. The criminal order provides return to the attacker if he completes it within the time limit. Each layer in the PLI model is expanded with middle processes for the methodology. The attacker uses shell companies to hide his identity and support each transaction for ML with apparently legitimate reasons. For actions of the AML specialist, this paper integrates the AML transaction monitoring with the Financial Action Task Force (FATF)'s Forty Recommendation. The defender needs to perform AML transaction monitoring with identifying suspicious financial activities based on money flow. Then, he needs to identify the actual beneficial owner of suspected companies with their share distributions. Both money flows and share distributions are visualized in data charts. Later, the defender shall report suspicious companies to the Financial Intelligence Unit (FIU), which will return the investigation result at the beginning of the next in-game month.

Keywords: AML, Simulation game, RegTech, FinTech, Game-based learning

1. Introduction

FinTech is a disruptive innovation with transforming financial services, but such disruption needs to be regulated and compiled with anti-money laundering (AML) and counterterrorist financing (CTF) laws to protect the global financial system (Duhaime, 2019). Both are regulated by RegTech to combat financial crime (Hanley-Giersch, 2019). Therefore, AML is one of the key factors in FinTech and RegTech. As existing research on AML education focuses on financial institutions and authority, it might ignore individual education for their AML awareness. The individuals might be exposed to the risk of being lured into money mules of money laundering (ML) (The Guardian, 2021).

This paper illustrates the design of a simulation game for AML to raise awareness of ML and AML through game-based learning with our simulation game. The game will be evaluated by students' feedback on the gaming for investigating the effects of knowledge delivery with the simulation game.

2. Literature review

2.1 Definition of AML and PLI model

"*AML aims to halt financial criminals from disguising illegally obtained funds as legitimate ones*" (ACAMS, n.d.). In other words, AML is to combat money laundering. ML consists of three stages: Placement, Layering, and Integration (United Nations, Office on Drugs and Crime, n.d.). Placement is to place illegally obtained income into financial institutions (ACAMS, n.d.). Layering is dividing dirty money by layers of legitimate transactions to hide the source of the dirty cash (ACAMS, n.d.). Integration is to support illegally obtained wealth with "apparent legitimacy" by re-entering the economy to disguise it as normal transactions from businesses and individuals (ACAMS, n.d.). All three stages of ML form the PLI model, which is the foundation of the ML method in this paper.

2.2 Financial Action Task Force Forty Recommendations

When discussing AML and CFT laws for the global financial system, it is unavoidable to introduce Financial Action Task Force (FATF) with its standardization on AML regulations and operations. Its Forty Recommendations published in 1990 is a comprehensive AML guideline for the international safeguards and governmental standards to combat financial crime (FATF, n.d.). Combining FATF Forty Recommendations with game-based learning on AML could help players stay grounded to the global standard.

2.3 Game-Based Learning With Simulation Game

Game-based learning (GBL) is a type of gameplay with defined learning outcomes (Shaffer, Halverson, Squire, & Gee, 2005) in behaviorism, cognitive, constructivism, humanism, and connectivism (University of Phoenix, n.d.). Plass et. al (2015) contributed to the foundations of the GBL with a model and design framework. The model is a continuous loop in general with a challenge, response, and feedback (Plass et.al, 2015). The design framework is integrated learning game design elements with four foundations: affect (i.e., constructivism), motivation (i.e., behaviorism), cognitive, and social or cultural (i.e. connectivism or humanism) (Plass et. al, 2015).

One of GBL examples in digital forms is simulation games. It serves the purpose of education to represent the player with a simulation with a focus on a mimicking real-life scenario (Kruk and Peterson, 2020) to facilitate "learning" (i.e. *acquiring or enhancing knowledge and skills*) and "simulation" (i.e. purpose to facilitate learning primarily or support learning indirectly) (Frasson and Blanchard, 2012). Although the simulation part focuses on *imitating one process by another process* for scientific purposes with typically perceiving physics elements (Hartmann, 1996), it could integrate financial and AML elements into the simulation to achieve GBL on AML.

2.4 Existing Business Simulation Games

As simulation games or Serious games provide individualized instructions and measure educational outcomes, they are a powerful delivering channel to achieve educational outcomes (Routledge, 2015). For business simulation games, a typical example is Harvard Business Simulations (n.d.) which integrates business concepts with realistic business scenarios to allow users to make decisions based on visualized data diagrams and charts. It provides a design direction for designing the methodology of this game.

2.5 Existing ML Simulation Games

The internet consists of ML simulation games. One example is the work from i-KYC (n.d.), which adopts a plot-based visual novel to educate players on ML concepts. Another example is the ML Simulator from Candlesan (n.d.), where a player shall roleplay a money launderer to launder a target amount of money with given methods each day and avoid being caught by the FBI.

2.6 Existing AML Simulation Games

Most of the anti-money laundering simulation games are designed for corporations.

For corporation training, Hernández Sánchez (2018) included risk management for ML in their game for organizational training purposes. Another example is True Office (True Office Learning, n.d.), which is a game-based training tool for compliance topics such as anti-money laundering.

For roleplaying with the theme of the corporation, Games4Substainability (n.d.) developed a 3D game called Anti Money Laundering, where players roleplay AML specialists to investigate the financial crime with the PLI model and provided AML-related glossary for references. Also, Anti ML Centre and PwC (2021) co-developed the AML pressure cooker, where players roleplay the Advisor of a suspicious company NaBook to identify whether it is secretly used for money laundering. During the investigation, players can access the dashboard and hint to learn the ML in gaming.

3. Project Methodology

3.1 Two Player Game Approach

As existing works specify the theme of either ML or AML, there are no AML simulation games for players to perform both ML and AML. Regarding this, the methodology adopts a two-player game approach with one player as a money launderer and another player as an AML specialist. Both players will combat each other to simulate the attack and defend during ML in a bank. The gameplay follows a generic plot with decisions to get endings based on their in-game performance.

3.2 Game-Based Learning With Plots

Our work is designed to link the GBL model with plots for both attacker and defender. Based on the GBL model, the game induces a challenge with introduction stories, receives responses from players, and gives them feedback with ending stories.

3.2.1 Challenge with introduction stories

For introduction stories, both stories are delivered in videos to explain the identity and mission of each player. Represented in visual and audio, the stories situate the theme and background to facilitate the cognition of their role. Additionally, it integrates with the emotional representation of affection. The attacker's story is inspired by the story of the world's famous money launderer Bruce Aitken, who laundered money for the dark side of a government but realized that he broke the law later (SCMP, 2022). Like Bruce's situation, our plot mimics the situation where the attacker realizes that he will be eliminated by the government with his dirty work and must earn $1,000,000 to escape overseas with sufficient capital to maintain his living. Besides, the defender's story informs him of the duty of being an AML specialist and the consequences of failing to safeguard the bank.

3.2.2 Receive response from players

After the introduction stories, players take action to respond to the game. The attacker receives dirty money from criminals privately and performs ML by the PLI model. The defender disturbs the attacker's ML activities by AML transaction monitoring and reports any companies with suspicious financial activities to the Financial Intelligence Unit (FIU). The response period consists of 6 months, where each month has 4 weeks for both players to respond. Each week, the attacker takes action first while the defender observes financial activities at the end of the week.

3.2.3 Give feedback to players with ending stories

After six months of the response period, the game analyses the in-game performance of both players and gives feedback to them with a performance summary and ending stories. For the performance summary, the attacker is evaluated with the success rate of laundered money (i.e. the amount of successfully laundered money over the received dirty money) and the percentage of the laundered money to the target goal of $1,000,000. The defender is evaluated with the accuracy rate of reported companies (i.e. the number of companies reported with actual ML activities over the number of companies reported) and the success rate of ML halted (i.e. the halted amount of laundered money over the total amount of laundered money).

Based on the evaluation, both players receive an ending story respectively. Figure 1 shows that the attacker has two ending stories with whether he can achieve the target goal. Figure 2 shows that the defender has three ending stories with two criteria: the accuracy rate of reported companies is not lower than the acceptable default and whether the attacker achieves his ML goal.

	Ending stories
Can earn the target goal $1,000,000	Good Ending (Attacker successfully escapes to overseas)
Cannot earn the target goal $1,000,000	Bad Ending (Attacker is caught by the government)

Figure 1: Ending stories for the attacker

		Can Attacker achieve his money laundering goal?	
		Yes	No
Is Accuracy rate lower than acceptance default?	Yes	Bad Ending (The bank is fined by the government while the defender is fired by the bank)	Neutral Ending (The defender protects the bank from money laundering, but the senior does not like too much unnecessary filing.)
	No		Good Ending (The defender protects the bank from money laundering and get a promotion)

Figure 2: Ending stories for the defender

As emotional events can provide clearer, more accurate, and more long-lasting delivery (Tyng et. al, 2017) to facilitate learning, the ending stories adopt different music and content depending on the game result to raise players relevant emotions. If the player wins the game, it will adopt happy theme music and plot to emphasize the happiness of winning. If he loses the game, it will adopt sad theme music and stories to emphasize the disappointment of losing.

3.2.4 Intense gameplay with monthly report

Sessions 3.2.1-3.2.3 form a general loop for the GBL model. However, if players keep playing all 24 in-game weeks to gain feedback, their attention start declining after 20 minutes (Bradbury, 2016) without a break. Therefore, we design the game by providing a monthly report to both players to send them intermediate feedback and pause the game for a break before proceeding to the next in-game month. For the attacker, the monthly report shows the estimated money flow trend of normal companies and shell companies reported by the defender to make a strategy. For the defender, it informs the defender once the attacker has attained each quarter of his target goal. Providing up-to-date information to both players can intensify the gameplay by motivating them to counter other players. If any player meets his winning goal in any in-game month, the game will end immediately by showing end game summary and ending stories.

3.3 Actions of the Attacker

The actions of the attacker consist of four layers, where each layer shall either keep the current action status or pass data to the next layer. The first layer is the source of dirty money, which is named as criminal order. The other three layers are the PLI model: placement, layering, and integration.

3.3.1 Attacker: Criminal order

Organised criminals use professional ML syndicates to conceal the illicit nature of funds sourced from criminal activities (Australian Federal Police, n.d.). As the attacker is a professional money launderer in the plot, he will receive several orders from criminals to launder their dirty money. Each order rewards the attacker with a percentage of the dirty money, but it has a time limit to fulfill the ML process.

3.3.2 Attacker: Placement

Placement is placing dirty money into the bank, but it is obvious for such practice because the attacker cannot provide a legitimate source for the placed money. Therefore, it needs a middle process for transforming dirty money into other forms of assets including casino tokens, cash funds, cash, gold, cryptocurrency, and foreign currency. Then, those assets will be transformed into three forms of currency including local currency, cryptocurrency, and foreign currency. Casino tokens and gold are sold to local currency while the cash and cash funds are assumed another representation of local currency. Last, those three forms of currency will be placed into the bank for the layering process later.

3.3.3 Attacker:Llayering

Layering needs to use layers of transactions to hide the originality of dirty money. The attacker should not use his personal identity directly to perform transactions risking being exposed to the bank. Instead, he should own a shell company to remote control other shell companies to perform transactions for layering. Such practice allows hiding his identity during the layering. Each transaction for layering is a Transaction object including sending status, receiving status, the week the transaction occurred, and the legitimate reason for the transaction. The sending status includes the name of the sender, the sent item type, and the sent amount. The receiving status includes the name of the receiver, the received item type, and the received amount. The week of the transaction occurred is named transaction week. The legitimate reason is a transaction type for money outflows of a company including purchase, operational expense, interest expense, lending, and investment. The relationship among the attacker, shell companies, and transaction are shown in Figure 3.

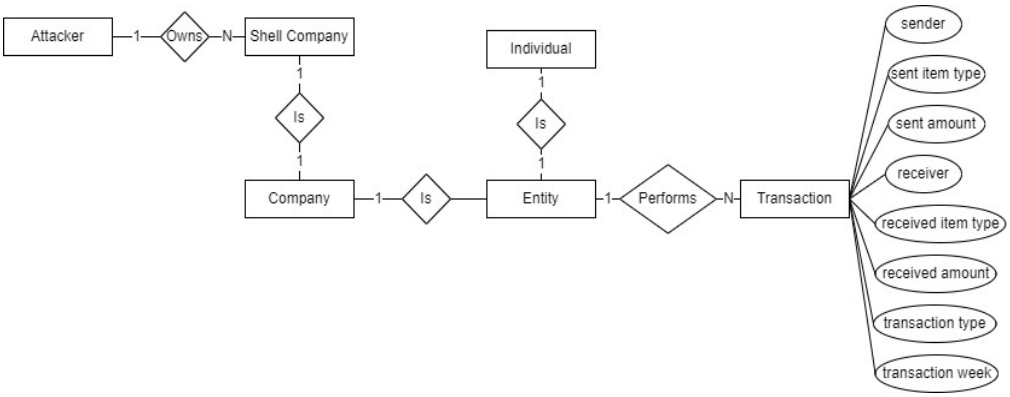

Figure 3: Entity Relationship Diagram in the Layering layer

To connect the placed currencies in the placement layer to this layer, we allow the attacker to spend all three types of currencies with local payments (i.e. onshore payments) and cross-border payments (i.e. offshore payments). Onshore payments are transactions using local currency and cryptocurrency while offshore payments use foreign currency and cryptocurrency. Depending on the attacker's strategy, he could keep performing a transaction after a transaction or stop processing.

3.3.4 Attacker: Integration

Integration is to support dirty money with apparent legitimacy to disguise as normal transactions from companies. Those transactions are from layering transactions, but their receiver is a specific bank account for both the attacker and criminals to extract laundered money and spend it as legitimate income. Before extracting the money, those transactions are checked by the bank with AML transaction monitoring. If it is caught by the bank, the bank account of shell companies will be frozen so the attacker will lose his effort of ML with the frozen account.

3.3.5 Summary

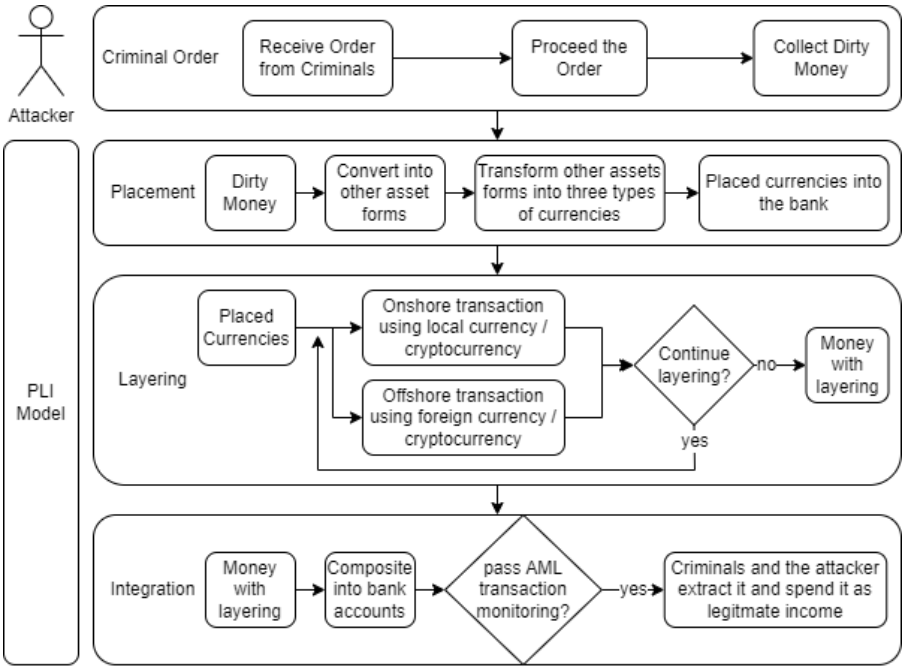

Figure 4: Summary of the attacker's actions

3.4 Actions of the Defender

The actions of the defender start from performing AML transaction monitoring to identify companies with suspicious financial activities. Then, the defender will identify the actual beneficial owner of the suspected companies by share distribution. Afterward, the defender can report all companies owned by the actual beneficial owner to the Financial Intelligence Unit (FIU) for further investigation.

3.4.1 Defender: AML transaction monitoring

AML transaction monitoring is to monitor customer transactions based on customer activity, which is developed by customer information and interactions currently and historically to access the client risk (SAS, 2022). A company generates money flows from its operations. If it is a shell company for money laundering, the money flows are from ML activities, which are transactions from the attacker. To identify the shell companies among all companies, the defender observes visualized money flows in a line chart each week among all transaction types to spot suspicious financial activities with abnormal patterns.

3.4.2 Defender: Identify actual beneficial owner

FATF Recommendation 10 (2012) stated that customers suspected of ML activities should be conducted with customer due diligence by identifying the actual beneficial owner with reliable and independent data sources. Once discovering any companies with suspicious financial activities, the defender should identify the actual beneficial owner by observing the share distribution, visualized by a pie chart. In our work, the actual

beneficial owner is the largest shareholder of a suspected company. If the defender is confident that the actual beneficial owner is the attacker's shell company, all companies with the particular shell company as the largest shareholder shall be reported to FIU.

3.4.3 Defender: Report suspicious companies to FIU

FATF Recommendation 20 (2012) stated that financial institutions with suspects of ML should be reported to the FIU regardless. After identifying the actual beneficial owner of any suspected companies, the defender can report these companies to the official institution FIU for further investigation. *The FIUs function as an intermediary between the private entities, subject to AML/CFT obligations, and law enforcement agencies* (Council of Europe, n.d.). During the investigation, banks may freeze banks accounts of reported companies with suspected ML (Deacons, 2020). In the game, assume the FIU can give investigation results of reported companies to the bank in a month. If the reported companies are one of the attacker's shell companies, the bank will keep freezing the bank account. Otherwise, it will unfreeze innocent bank accounts. To prevent abuse of reporting to achieve guaranteed winning for the defender, the minimum accuracy of reporting has an acceptable default of 70%.

3.4.4 Summary

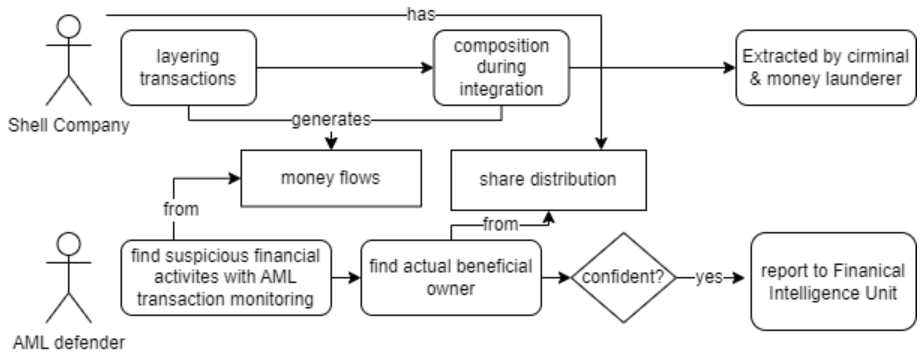

Figure 5: Summary of the defender's actions

4. Implementation

4.1 Game Flow

If a room is matched with two players, the room host can start the game. At the beginning of the game, players select their roles and watch associated introduction stories. Both players perform actions to give a response. For the attacker, it is criminal order and the PLI model. For the defender, it is the AML transaction monitoring, identifying the actual beneficial owners and reporting suspicious companies, where the share distribution and normal companies' money flow are stored in an embedded CSV file. After the game ends, the game gives feedback to players with an evaluation summary and ending stories. The game flow is shown in Figure 6.

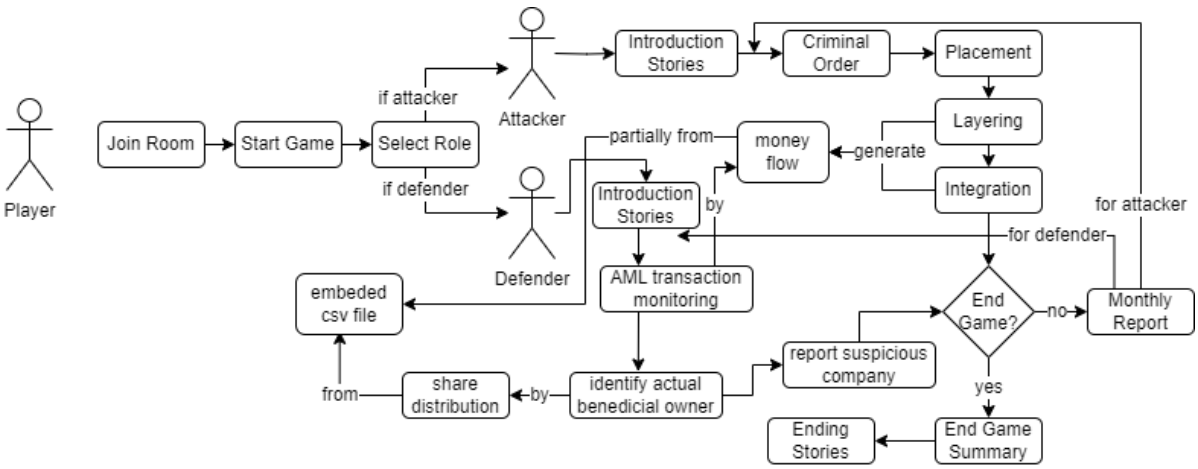

Figure 6: Graphical Expression in the game flow

4.2 Networking for two Player Game

As our work is implemented with Unity, the networking among players adopts the Photon Unity 3D Networking (PUN) framework from Photon (n.d.), which is a peer-to-peer (P2P) networking solution. This framework is hosted by Pun's cloud services for room matching and data transmission. Each player is a peer who holds all components and enables partial components based on the in-game scenario. Figure 7 shows the networking architecture for the game.

Figure 7: Networking architecture diagram for the game

4.3 Role Selection

As each peer holds all components, when players select to be either attacker or defender, a role selection mechanism (see Figure 8) restricts access to them to prevent either the case that one player selects two roles or the case that one role is selected by two players.

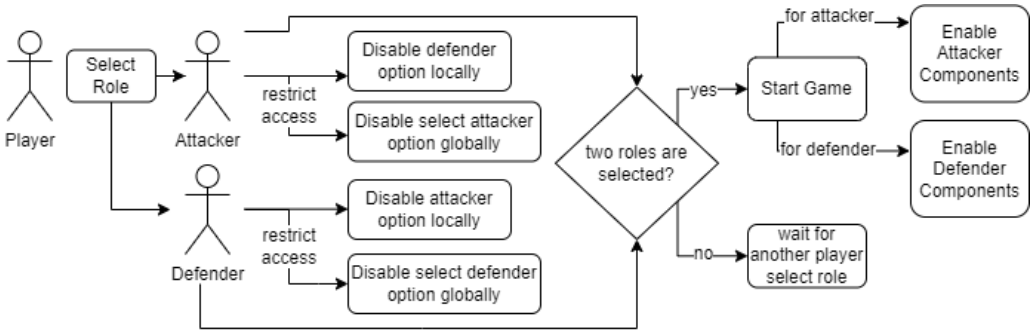

Figure 8: Detailed Flow of role selection

5. Evaluation

The effectiveness of our AML simulation game is evaluated by comparing the pre-surveys and post-surveys with 50 students invited in total. Both surveys are conducted to measure their overall score in awareness of ML and AML. Compared to the pre-surveys, the results of post-surveys showed an increase in scores of awareness in both ML and anti-money laundering. In other words, students responded that they will be more aware of the ML process (i.e. placement, layering, and integration) and AML concepts like transaction monitoring and FATF in their daily life. Besides, students reported that they had heard of ML and AML but had not heard of FATF and its Forty Recommendations, showing the need of integrating official institutions such as FIU and FATF in the education of AML to the students. As the students reported that they received useful information from the plots and in-game actions, the design of GBL with plots was positively received by the students. However, it is reported that it is too time-consuming to spend at least an hour to complete the gaming with 24 in-game weeks. Another suggestion from the students is adding a glossary of terms for explaining keywords used in the plots and in-game actions. Therefore, the results of surveys suggest that the game can educate users with concepts of ML and AML including the ML circle, and overview of regulation institutions of AML, but it can be further improved by adjusting the time length of gaming and adding a glossary of terms.

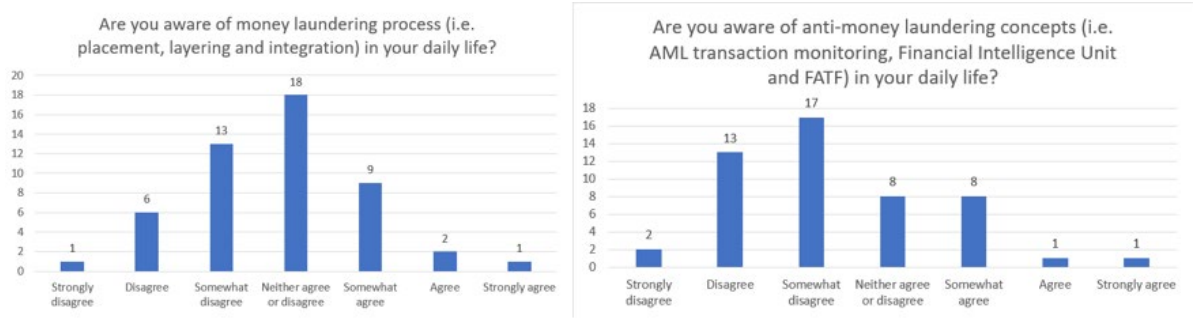

Figure 9: Results for pre-survey on the awareness in ML and AML

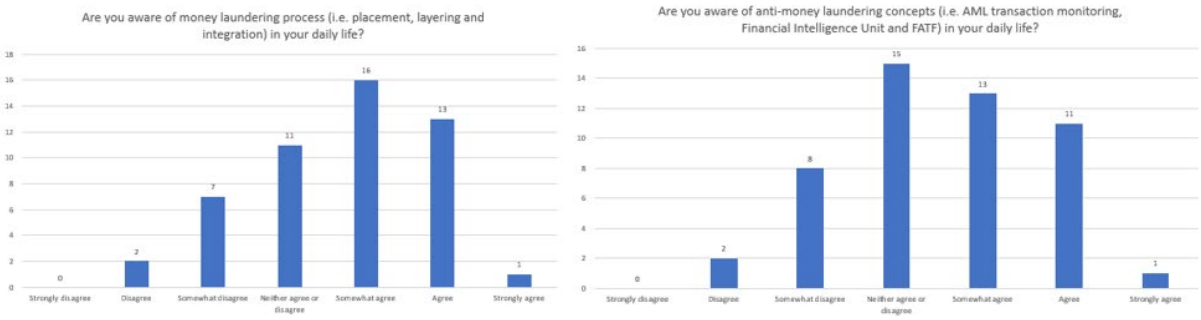

Figure 10: Results for post-survey on the awareness in ML and AML

6. Conclusion

This paper illustrates the design of a simulation game for AML implemented by Unity. The objective of the design is to educate individuals about ML and AML knowledge to raise awareness in daily life to reduce the risk of being a money mule. The game consists of two roles: the money launderer as the attacker and the AML specialist as the defender. Both players combat each other to attack and defend during ML in a bank. The game delivers game-based learning with plots including introduction stories, in-game actions, and ending stories. The introduction stories illustrate the background and mission of each player. The attacker needs to earn a target amount of $1,000,000 with ML for his saving in migrating overseas to escape the government. The defender needs to safeguard the bank from ML for his job. The in-game actions have 24 in-game weeks for both players to counter other players' actions. The attacker will receive dirty money from criminals and perform ML using the PLI model (i.e. placement, layering, and integration). He will use a shell company to remote control other shell companies to perform transactions to disguise the ML as business operations and integrate the money into the bank. The defender will perform AML transaction monitoring to identify companies with suspicious financial activities. Then, based on FATF Recommendation 10, the defender will identify the actual beneficial owner of suspected companies with share distribution. Based on FATF Recommendation 20, he will report all companies owned by the actual beneficial owner to the FIU for further investigation and freeze their accounts before receiving the investigation result. If the investigation result validates the report, the bank will keep freezing the bank accounts to halt money laundering. Otherwise, it will unfreeze the bank accounts. Before the ending stories, the game will show an end-game summary to evaluate players' performance. Then, it will play ending stories based on the player's performance to give feedback. To intensify the gameplay, there is a monthly report at the beginning of each month to provide players with up-to-date information to make more valid decisions.

This simulation game is developed by Unity. The money flow of normal companies and the share distribution of all companies are stored in an embedded CSV file. The networking adopts the Photon Unity Network #D framework for its peer-to-peer solutions, which are hosted by Photon Cloud services. As a P2P game, each peer holds all components and enables part of them based on gaming scenarios. Therefore, a role selection mechanism is discussed to prevent either the case that one player selects more than one role or the case that one role is selected by more than one player.

The evaluation of this paper is conducted by comparing pre-surveys and post-surveys of 50 students. The results of surveys suggest that the game can educate users with concepts of ML and AML including the ML

circle, and overview of regulation institutions of AML, but it can be further improved by adjusting the time length of gaming and adding a glossary of terms.

The limitations of this paper's work are acknowledged.

- AML of the banking industry is confidential. Our work has no access to the most detailed information and solution of current industrial practice.
- Methods of ML should not be limited to companies and considered using money mules.
- As ML could vary based on the money launderer's practice, the design tries to provide a more generic approach. Details like transaction type of companies are assets forms in placement might not be the same as the real-life scenario.
- We did not have money flows data from companies to simulate the financial activities of normal companies without money laundering.
- The attacker could memorize all the money flows of normal companies and pretend normal companies with the memorized money flows. In real scenarios, the attacker needs to figure out the normal pattern of money flow by themselves when attempting to use shell companies for money laundering. Data for the attacker to guess such a normal pattern is not provided in this work.
- Evaluations of the end game are more focused on the defender with providing the confirmed reports of the attacker's ML acts. However, the reason why the ML activities of the attacker are caught by the defender is not answered by both parties.

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When Design Gets in the way: Student Learning and Digital Escape Game

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Abstract: Escape games are known for their potential to engage students and are becoming a popular way to teach content in a variation of subjects, e.g., chemistry (Peleg et al., 2019), music (Babazadeh et al., 2022), and financial literacy (Bisanti et al., 2022). It is also a rapidly developing field of research (Veldkamp et al., 2020, Taraldsen et al., 2022). The importance of the debrief stage after playing and its role in ensuring learning outcomes has been discussed (Babazadeh et al., 2022). However, investigating students' learning while playing the game is needed to understand how they can be used in the classroom and continue improving the design of future escape games. In addition, there is still little research on escape games used online, in a digital format.

This study explores the students' experience of learning when playing the digital escape game *Radioaktiv* over video conference. Video data of six pairs of students playing the game were collected at a Norwegian University. Interaction analysis was conducted on representative data extracts to answer the following research question: *How did the students' experience of learning unfold while playing the digital escape game Radioaktiv?* Findings show that design choices came in the way of students' learning and reveal the importance of just-in-time and adapted feedback. Implications for this study are the importance of playtesting the escape game, especially when it comes to designing the puzzles and feedback loops. The present study also shows the necessity of the teacher: the automatised feedback system from the digital escape game cannot replace the role of the teacher during gameplay. This is especially true in the context of online learning where students can more easily feel left alone. Digital escape games as a learning activity should always be implemented within a clear pedagogical design.

Keywords: Digital escape game, Escape game, Higher education, Online learning

1. Introduction

Escape games for educational purposes have been rapidly developing in the last year and used in many different subjects, from chemistry (Peleg et al., 2019) to financial literacy (Bisanti et al., 2022). Research publications on the topic have multiplied in later years but review studies of this field still point at the need for more systematic research (Taraldsen et al., 2022; Veldkamp et al., 2020). In addition, most of the games investigated in the published studies are still performed in analogue contexts, e.g., in the context of a classroom (Babazadeh et al., 2022) or an archive room (Koenig et al., 2022).

Case reports of escape games used online or for the remote classroom have been published in recent years, especially within the health sector (e.g., Vergne et al., 2020; Abdul Rahim, 2022; Helbing et al., 2022). Some research papers investigate the design process of migrating an escape game online (Kutzin et al., 2021; Videnovik et al., 2022). However, pedagogical research on the use of these games in the context of online teaching and learning remains limited (e.g., Rodríguez-Ferrer et al., 2022; Vestal et al., 2021).

The present study proposes one example of such research by investigating the use of the digital escape game *Radioaktiv* within an online course for student teachers at a Norwegian university. Through interaction analysis of video data of students playing the game, I will explore the following research question: *How did the students' experience of learning unfold while playing the digital escape game Radioaktiv?*

2. Review

Review studies on escape room in education show the rapid development of this research field, even though they also point at the lack of systematic research (Taraldsen et al., 2022; Veldkamp et al., 2020). Both studies describe escape games as a generally positive experience and that most students showed engagement and enjoyment, and participated actively. In accordance with these findings, studies of educational escape games have reported that students are engaged and enjoyed the learning activity (e.g., Peleg et al., 2019; Cain, 2019; Ho, 2018). A previous study of *Radioaktiv* found that the digital escape game was engaging for students and that their experience of engagement was focused on the feeling of competition and the desire to complete tasks more than the narrative (Cruaud, in review). Contrasting with most studies, Duncan (2020) reports no difference in engagement between the traditional learning activities and the escape game used with grade 3 students learning 21st-century skills. When it comes to learning, Olombel et al. (2021) reports no difference in achieving learning outcomes between using the escape game or the non-playful learning activity. However, different

rationales for using escape games are reported in the field, e.g., "to expose students to scenarios where they can experience a situation", to "create a real-life atmosphere in their use of an escape room" (quasi-realistic scenarios), or "as a setting for learning to apply 21st-century skills" (Taraldsen et al., 2022, p. 176).

I will now 'zoom in' on three studies of online escape games used in higher education settings: a qualitative study of a synchronous and fully online escape game where teams of health science university students play in online rooms (Rodríguez-Ferrer et al., 2022); an online asynchronous escape game using google forms where individual first-semester students play a game regarding patient safety (Vestal et al., 2021); and a fully online and synchronous escape game on gender violence played by teams of university students from a social education course (Manzano-León et al., 2021).

All three studies report that using the escape games was a positive experience for the students. Manzano-León et al. (2021, p. 6) describe it as a "playful and immersive experience" and noted greater participation and engagement.

All three studies also agree on the effectiveness of this pedagogical approach to enhance the students' knowledge and awareness of specific topics. Rodríguez-Ferrer et al. (2022, p. 109) also point out that "the appropriate design and use of educational escape rooms can have a positive impact on the motivation, flow, and perceived learning of university students."

Vestal et al. (2021, p. 468) report that "the game-like feel of the activity provided a more "relaxed setting" that was both creative and informative." However, this can be nuanced by Manzano-León et al. (2021, p. 7)'s finding that some students were stressed, expressed fear of failing and required continuous cues to continue the game.

The teacher and researchers were present to answer students' questions and give cues in two studies. In the last one, the activity was conducted asynchronously, and students were not provided any real-time support (Vestal et al., 2021). The same authors comment that students could have used a facilitator-led debriefing in addition to the self-debriefing provided to "further enhance students' learning" (Vestal et al., 2021, p. 468).

In conclusion, all three studies seem to agree with Rodríguez-Ferrer et al. (2022, p. 109)'s affirmation that "online escape rooms can be a valuable educational resource" in addition to being highly reusable.

3. Methods

3.1 Investigating Radioaktiv, A Digital Escape Game for the Science Class

The present paper is part of the research project Escape Games for Learning, investigating the digitalisation of escape games for educational use through the study of *Radioaktiv*, a game for the science class (*naturfag*). The game is set in the laboratory of Dr. Doppler. After an alarm goes off, the two players have to make their way through the locked doors of the laboratory to save Dr. Doppler from radioactive exposure. *Radioaktiv* is played through a web browser. Two players team up and each open their own webpage, e.g., player 1 or player 2. Players do not have access to the same information and must communicate and collaborate to advance in the game. There are five main puzzles taking different forms (e.g., question with hints in the text, crossword, a table of nuclear elements to fill) but all are solved by entering the correct code in a padlock on the webpage. Both players enter the code individually on their webpage to open the next section of the game.

As part of the research project, *Radioaktiv* was played by teacher students in one of their online courses at a Norwegian university. Six pairs of students were filmed during playtime and the guided conversation afterwards, all of it over video conference. In the present paper only the playtime part of the recording was used.

3.2 Interaction Analysis: Looking at Dialogue

In this study, I am interested in looking at students' experience of learning while playing the digital escape game *Radioaktiv*. Here, learning is understood as the negotiation of meanings within a dialogic space (Wegerif, 2007). Learning is the taking of different perspectives through dialogue, in other words making meaning through the interactions between the students, and between the students and the game. Analysing interactions and dialogue is then a way of understanding how learning unfolds between students within the context of playing the escape game (Linell, 1998).

Interaction analysis of selected sequences was conducted (Jordan & Henderson, 1995). First, in the familiarisation step of the analysis I watched the recordings of students playing and took notes of what I found interesting, surprising or parts I wanted to come back to. Second, I reviewed closely the video recordings and marked recurring sequences across the data set (Derry et al., 2010). Third, I selected sequences within one

episode and analysed them further through interaction analysis. In this last part of the analysis, I used the transcripts from the recordings. I translated the two sequences presented in this paper from Norwegian to English trying to stick as close as possible to the students' way of speaking. The extracts presented in this article have been anonymised and the participants' names are pseudonyms.

The episode selected will be called thereafter "the gamma ray episode." There are several reasons for selecting this episode, both analytic and pragmatic. The gamma ray episode is representative of what happens several places in the data set, across all six groups. However, these sequences are also rather short and then, easier to report within the frame of this paper than longer episodes.

Out of the six groups of the data collection, five completed the puzzle from the Gamma ray episode (see Table 1). Group 6 did not, as they ran out of time earlier in the game. Four of the groups followed a similar pattern, that I will describe and analyse further, through the example of group 1 and 4. Group 3 followed a similar pattern, but they also encountered a major technical issue while solving the puzzle. Their attention was therefore turning towards it more than the puzzle, making the interaction sequence messier to report here.

4. Gamma Rays: Analysing how Learning Unfolds

I will now use interaction analysis of specific sequences of playtime to analyse the students' experience of learning while playing *Radioaktiv*.

4.1 Context: Placing the Episode Within the Game and the Data

The gamma ray episode is the 5th and last puzzle the students encounter in *Radioaktiv*. The puzzle right before was about the material needed to protect against radiation. In doing so it introduced the three types of radiation – alpha, beta, gamma. Students should then come to puzzle 5 with some knowledge of the answer to the question asked.

In Puzzle 5 both players are in different places at a hospital. Player 1 is in the waiting room, anxious about Player 2 and Dr. Doppler and has access to a short narrative text and a video on how each type of radiation affects the human body. Player 2 is undertaking medical checks with a radiologist and is presented with a question "Do you remember what type of radiation the lead suit protected you from?" The answer to this question, "gamma radiation" (in Norwegian, written in one word '*gammastråling'*) is the code the players need to unlock the last padlock.

Before we dive into the sequences of interaction of group 1 and 4, the following table summarizes the gamma episodes across the six groups. All the 5 groups who reached this puzzle had the correct answer from the start. However, none of the groups typed it correctly, or I should say, in the expected way. As their answers were not accepted, most groups went mechanically through the list of all three radiation types, before (sometimes with help from the researcher) entering their first answer again, gamma radiation (*gammastråling*), this time in the accepted form, and thus solving the puzzle.

Table 1: Overview of gamma episodes

Data session	Wrote "gamma" first	Went through the whole list of radiation	Help from researcher	Time to solve the task
1	yes	yes	no	2 min
2	yes	no	yes	1,5 min
3	yes	yes	yes	4 min
4	yes	yes	no	4,5 min
5	yes	no	no	2 min
6	*Did not reach this task*	*Did not reach this task*	*Did not reach this task*	*Did not reach this task*

4.2 Sequence #1: Per and Malin (Group 1)

Since the start of the game, Per and Malin (group 1) are communicating well, sharing information and solving the puzzles quite fast. They both seem engaged in the tasks and often show signs of excitement and laughter. In

the following sequence of interaction, they reach the 5th puzzle. Malin reads up the question and Per answers immediately with the correct answer 'gamma.' Malin agrees also immediately and they both type in the answer on their respective browser. Per's answer is not accepted by the game, and he tries typing in the other two types of radiation 'alpha', 'beta' before repeating aloud twice that 'gamma' has to be the answer. Malin suggests that they should write the whole word, including 'radiation'. Per first types in the other two types of radiation in the way suggested by Malin, while Malin types in 'gamma radiation' and solves the puzzle.

1 Malin: [reading] "Do you remember what type of radiation the lead suit protected you from?"
2 Per: Gamma.
3 Malin: Yes.
4 Per: It must be gamma radiation then!
5 Malin: Uh yes… [typing]
6 Per: Uh gamma maybe, no! Uuuh… [scrunching up his face]
7 Alpha then. Beta? Eh? [reading] "Sorry the answer is not correct, try again."
8 Not gamma radiation? It has to be though… It has to be.
9 Malin: Do they want us to write the whole word somehow?
10 Per: Yes, maybe if we write like al-pha ra-dia-tion… Be-ta ra-dia-tion… [typing as he enunciates]
11 Malin: Gamma radiation was correct!

Figure 1: Sequence of interaction #1 – Group 1

In this sequence we can see three steps of interaction, a pattern that can be found in the other gamma episodes. When Malin and Per enter the interaction, they are sure of the answer (line 2-5). They have encountered it in the previous puzzle, so they do not hesitate when Malin reads up the question "Do you remember what type of radiation the lead suit protected you from?" (line 1). However, when they type in 'gamma' they receive negative feedback from the game 'Sorry the answer is not correct, try again.' Per seems to be confused by the fact that his answer is not accepted (line 6). His hesitation shows in the sounds and the face he makes. Per, who knew the answer without hesitation a few seconds ago, now turns to the other two types of radiation and enters them in (line 7). Each time he gets the same negative feedback from the game. His confusion is clear when he goes back to saying that his first answer 'gamma' must be the solution, but this time with some doubt in his voice (line 8). It is interesting that when Malin suggests that they might need to spell out the whole word, including 'radiation' (line 9), Per first tries to type in 'alpha radiation' and then 'beta radiation.' Even though he was sure of the answer at first, he now goes through the list once more, in a mechanical and alphabetical fashion (line 10). Malin types in 'gamma radiation' first and solves the puzzle. When she gets the positive feedback from the game (the lock opens, and the next page is loaded) she exclaims "gamma radiation was correct!" (line 11).

This sequence shows how the negative feedback from the game, based on the spelling of the answer and not its correctness, confused students. Instead of reinforcing what they have learned in the previous task – the impact of different types of radiation – this puzzle makes Per doubt what he had learned. His confusion does not open up for a discussion of the subject, instead, their whole conversation is focused on how to spell the answer correctly. When Per starts typing in all the different types of radiation, it shows that his answers are not linked to any subject thinking. He does not weigh in the difference between alpha, beta, or gamma radiation, but answers mechanically in order to unlock the puzzle. In other words, Per and Malin are not engaging with the subject matter, but only want to find the correct code. The design of the puzzle, and especially how the answer is supposed to be typed in, guides the conversation between the students towards trivial details instead of the subject content.

4.3 Sequence #2: Kjetil and Stefan (Group 4)

During the whole playtime Kjetil and Stefan (group 4) are very comfortable with each other. They are joking and teasing each other. In the following sequence we see how they solve the gamma ray puzzle. When Kjetil reads the question, Stefan answers immediately and seems very sure of his answer. Kjetil types the answer in but gets negative feedback from the game and start suggesting other answers. Stefan watches a video about the different type of radiation and confirms that he thinks his answer, gamma, is the correct one. However, Kjetil is now sure that the answer is alpha. The students discuss the different types of radiation and agree on gamma. They try to find different ways of typing in the answer until Stefan writes the correct form "gamma radiation" and they solve the puzzle.

1 Kjetil: [reading] "Do you remember what type of radiation the lead suit protected you from?" What type of radiation was the most dangerous?
2 Stefan: yes, gamma.
3 Kjetil: [typing] no, it wasn't the correct answer.
4 Stefan: wasn't it gamma that was the most dangerous?
5 Kjetil: But it may be that the answer is on a different [unclear] then.
6 Do you remember what type of radiation the lead suit protected me from?
7 Stefan: wasn't it…?
8 Kjetil: Alpha. Alpha, was that it? I think it was the opposite in fact. Beta? We have to write all of them then, alpha, beta, gamma.
9 Stefan: Let's see. I'll just watch the video then.
10 Kjetil: You do have a video, right? [smiles]
11 [Stefan watches the video – silence for 1:40]
12 Stefan: From what I could see so it is gamma now.
13 Kjetil: No, it's alpha that's the most dangerous.
14 Stefan: Is that it?
15 Kjetil: Yes, isn't it?
16 Stefan: Alpha is stopped by the skin they said, so… But beta comes further in.
17 Kjetil: No…
18 Stefan: And gamma. Gamma goes all the way in to the organs.
19 Kjetil: Yes, you got something here… How can I write gamma, if I can't write it? Do you have another hint, or?
20 Stefan: No it just says "What type of radiation was the most dangerous?" I tried writing both alpha, beta and gamma with big and small letters.
21 Kjetil: Yes, and starting with a big and…
22 Stefan: So if it isn't that…
23 Kjetil: Is it the symbol then? How is the symbol? The symbol for gamma.
24 Stefan: Y
25 Kjetil: Y?
26 Stefan: Well, it looks like a y, but it is of course a Greek letter that is pronounced gamma.
27 Kjetil: Yes, but how do you make it then?
28 Stefan: Well, I can do it in in in Word.
29 Kjetil: Yes.
30 Stefan: But…
31 Kjetil: It doesn't help me that YOU can make it in Word. I have to make it in Word myself too.
32 Stefan: Yep. I went through.
33 Kjetil: That was it? That was it.
34 Stefan: Gamma radiation, gamma radiation [gammastråling].
35 Kjetil: Yes, what did you write?
36 Stefan: Gamma radiation.
37 Kjetil: You wrote gamma radiation? [laughs, giggles]
38 Stefan: Yes. [smiles]
39 Kjetil: In one word, just with small letters?
40 Stefan: Yes.
41 Kjetil: Yes.

Figure 2: Sequence of interaction #2 – Group 4

This sequence also starts with the students being sure of the answer to solve the puzzle. When Kjetil reads the question (line 1), Stefan immediately answers "gamma" (line 2). Kjetil accepts the answer as he immediately types it in, but he gets negative feedback from the game (line 3). Stefan, confused that the answer was not accepted, keeps wondering out loud about gamma not being the answer in a hesitant voice (line 4 and 7). Kjetil suddenly suggests alpha as an answer, but almost immediately changes his mind and in the end suggests that they have to write all the different types of radiation in the padlock (line 8). Stefan then says that he will watch

the video provided on his webpage (line 9) and both students are silent while he watches (line 11). When he is done watching, Stefan states that gamma should be the answer (line 12). But Kjetil disagrees and says that alpha is the most dangerous radiation (line 13). When both students discuss the different types of radiation (line 14-18), Stefan quotes what he has seen in the video "they said" (line 16). Kjetil agrees on the answer (line 19) and follows a discussion on how to write the word correctly in order to solve the puzzle (line 19-31). Stefan finds the correct answer and unlocks the last webpage (line 32). He shares the answer with Kjetil (line 34) and explains how to spell it correctly (line 35-41).

In this sequence we can see the same three steps of being sure of the answer, being confused by the negative feedback from the game, which leads to trying out other answers mechanically (lines 8 & 20), and finally solving the puzzle. The students, and especially Stefan who was sure of the answer, start hesitating and doubting what they had learned in the previous puzzle. Unlike the first sequence, this confusion does not only lead to trying out mechanically different answers. When Stefan decides to watch the video provided, a discussion about the subject matter is introduced. The video becomes an extra voice in the conversation, as suggested by the use of the pronoun "they" to represent the video and its narrator, when Stefan quotes from what he had just seen "alpha is stopped by the skin they said" (line 16). Stefan takes on a didactic role and explains how the different types of radiation affects the human body, in the same order as they were presented in the video. In doing so, he includes the video as a voice in their interaction which supports their learning. A major part of the student interactions during this sequence is still, however, focussed on figuring out how to spell the answer in a way that will be accepted by the game. In other words, the design of the answer of this puzzle, takes the most space in the interaction and is not related to subject matter. As an example, the students start discussing how to type Greek letters in Word (line 23-31). Where the video acts as a support in the students' learning, the game and its design come in the way of their learning as it guides the dialogue away from the matter at hand.

5. Discussion

In the analysis of interaction sequences, I have found that the design of the game, and especially how the answers were to be typed in, guided the conversation between students away from the subject matter and towards trivial details. Vestal et al. (2021, p. 468) have also encountered this issue when designing their asynchronous escape game on Google Forms. They had to decide whether to limit the number of accepted answers by having to type in "grammatically identical" sentences in the short answer field or opening for all types of answer – even incorrect ones – so that students could more easily move from puzzles to puzzles. In the end, the authors were not satisfied with their solution of accepting all answers and mentioned that this difficulty needed to be solved in a future iteration.

This design issue could also have been minimized or avoided by giving a clear feedback or cue instead of a message only saying the answer was incorrect. Manzano-León et al. (2021, p. 4) in their instructions for players precise for example that all answers need to be written in lowercase and without accents to limit the number of correct answers being marked as wrong by the game. This finding emphasises the importance of designing good hints, but also a good feedback system.

As the analysis has shown, all teams of students encountered the same issue and followed a similar pattern of being sure of the answer, then confused, and finally testing mechanically all possible answers. This finding shows the importance of playtesting the game. In a future iteration of *Radioaktiv*, this puzzle, the hints connected to it, and the way the answer is typed in should be reviewed and improved to avoid this unnecessary confusion that comes in the way of the students' experience of learning. Some groups received extra feedback on this puzzle as the researcher provided hints when it was clear that the students had the correct answer but struggled to type it in correctly. This demonstrates the importance of the teacher–or game master–in providing just-in-time feedback to students. In their study, Vestal et al. (2021, p. 468) also had no real-time support in place and concluded their article with reflecting on the need for teacher-led debriefings in further iterations. Manzano-León et al. (2021, p. 7) also found that some students were afraid of failing and required continuous support from the teacher or researcher in form of cues all along the game. This extra support, adapted to the students' needs, can only happen when the teacher is present and able to move from groups to groups. In the case of asynchronous escape games or when the teacher cannot communicate with students directly for other reasons, the cues and feedback system have to be sturdier and more flexible at the same time, e.g., through providing different levels of feedback and hints to different students. Some reported studies have for example used multiple layers of cues that students could choose to read or not, or sometimes even buy with time penalties (Cain, 2019; Veldkamp et al., 2020). However, Taraldsen et al. (2022, p. 178) also found that having too many

hints can move the students' focus away from the subject matter. The balance between too many and too few clues can be difficult to find and it might not be the same for all students.

6. Conclusion

This study analyses an example of digital escape game used in fully online learning settings, where teachers were providing no or little support to the students during playtime. The findings show the importance of playtesting the game to avoid small design issue taking too much space in the students' conversations. Details that could seem insignificant can come in the way of learning, by wrongly providing negative feedback or simply by focussing the students' attention on trivial details instead of the subject matter. Another implication is the need for adapted just-in-time feedback to reduce the risk of students being stuck for design reasons while they in fact know the correct answer. This shows that ideally the teacher would be available for students to get extra clues or support when needed and that it is difficult, if not impossible, to replace the teacher's role. A last implication of this study is the need for a clear pedagogical design that integrates puzzles, subject content, and play elements. Subject content elements (like the video in the sequences analysed) should be more naturally integrated in the gameplay to ensure that students will in fact use them in their interactions. This can lead to richer discussions on the subject with the videos or external support providing a new voice in the conversation.

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Design of an Educational Escape Room by Future Teachers

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Abstract: As educators seek innovative ways to engage students in the learning process, educational escape rooms have emerged as a promising motivational learning strategy. This paper presents a study on the design and playing of such escape rooms by pre-service secondary mathematics and informatics teachers using online tools. The study involved students collaboratively creating their escape rooms and introducing them to their peers. We gathered data through observation, questionnaires, evaluation cards, and their webpages regarding their opinions on the potential of these rooms as a teaching tool. Results indicate that most students found the educational escape rooms to be highly engaging and useful in promoting collaboration, and problem-solving skills. Therefore, they are open to using educational escape rooms in their future teaching. The study sheds light on the potential of student-led design of educational escape rooms as a means of preparing future teachers to incorporate this motivational tool into their teaching practice, with implications for teacher education programs and classroom practice.

Keywords: Escape room, Pre-Service teacher, Design, Motivation

1. Introduction

The use of escape rooms as an educational tool is nowadays an innovative approach to learning that has gained popularity. Escape rooms are physical or digital games that require players to solve puzzles and clues to "escape" a locked room or virtual environment within a set time frame.

In this scientific paper, we explore the use of digital educational escape rooms as a means of preparing pre-service informatics and mathematics teachers at the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava. Specifically, we investigate how students evaluate designs of the escape rooms using the digital online tool Room Escape Maker https://roomescapemaker.com/. We were also interested in their opinions on the impact of the use of escape rooms on students during classes.

The significance of our research lies in its potential to promote this new learning method in education. By incorporating educational escape rooms into pre-service teacher preparation programs, universities can equip future educators with the skills and knowledge needed to create engaging and dynamic learning environments for their students.

In the following sections, we provide a literature review on the use of educational escape rooms in education, describe the methodology of our study, present our findings, and discuss their implications for teaching and preparation of future teachers.

2. Theoretical Background

The escape rooms are live-action, team-based games where players must discover clues, solve puzzles, and accomplish tasks in one or more rooms to achieve a specific goal, usually escaping from the room, within a limited amount of time (Nicholson, 2015).

Escape rooms are a relatively new concept that has gained immense popularity in recent years. According to an analysis by International Escape Room Markets (2019), it is estimated that there were more than 50,000 escape rooms in the world in 2019.

In addition to the common escape games designed primarily for entertainment, educational escape games are also becoming increasingly popular. Educational escape rooms are problem-style scenarios that are designed with specific learning outcomes in mind. They require learners to participate in collaborative playful activities, explicitly designed for knowledge acquisition or skill development. So, they need to accomplish specific goals by solving puzzles linked to learning objectives in a limited amount of time. They are usually physical or hybrid games that take place in classrooms or labs, with a time limit of 60 minutes or less and a team size of 5 or more (Fotaris & Mastoras, 2019).

Overall, the potential of educational escape rooms as an innovative and engaging method for promoting active learning is promising. Several studies suggest that appropriately designed educational escape rooms can increase student motivation and support their interest in learning (Taraldsen et al., 2022; Fotaris & Mastoras,

2019; Veldkamp et al., 2020; Videnovik et al., 2022; Manzano-León et al., 2021; Fotaris & Mastoras, 2022). According to Fotaris and Mastoras (2019), "…educational escape rooms can provide an enjoyable experience that immerses students as active participants in the learning environment." Solving escape rooms help learners in comprehending the importance of viewing problems from various angles, gives them opportunities to engage in collaborative teamwork, encourages them to stay committed to the task, promotes strong social relationships, encourages team spirit, and facilitates various learning benefits through group discussions (Fotaris & Mastoras, 2019).

From the point of view of pedagogy, escape rooms are based on a social-constructivist approach (Vygotsky, 1978), where learners construct their knowledge based on real-time experiences of advancing through several challenges in the escape room. They need to face new and often complex problems, which can be solved by interacting with their peers and getting support from their tutor.

Escape rooms can be used as a method to learn a variety of subjects. According to a recent review study (Taraldsen et al., 2022), the most frequently mentioned are healthcare professions, science, technology, engineering, and mathematics (STEM). Fotaris and Mastoras (2019) reached similar results in their review study. They list the most common subjects as health and welfare, natural sciences, mathematics and statistics, social sciences, journalism, and information and communication technologies. There are examples of the use of escape rooms at different levels of education, but they are most used in higher education (Taraldsen et al., 2022; Fotaris, and Mastoras, 2019; Veldkamp et al., 2020).

Academically focused escape rooms were popularized by Breakout EDU, an immersive learning games platform founded in 2015 (Duggins, 2019). This platform provides escape room kits for instructors. Educational institutions and libraries have started to integrate this initiative into their programs or to develop their educational escape rooms. The research on this topic started to gain popularity and various interesting results were published.

Fotaris and Mastoras (2019), based on an analysis of 68 studies, concluded that "results seem to indicate that escape rooms are innovative, active, collaborative and constructivist instructional approaches that can shape learning more powerfully than conventional teaching." They also state: "Additionally, they allow learners to engage in an activity that rewards teamwork, creativity, decision-making, leadership, communication, and critical thinking."

Huang, Kuo, and Chen (2020) investigated the effect of digital escape rooms on students' learning performance, motivation, and problem-solving. They conducted research with an experimental and control group consisting of 20 fourth-grade students in each group. The experimental group used digital escape rooms for a 10-week duration, while the comparison group used direct teaching methods. The results showed an increase in learning motivation and problem-solving abilities in the experimental group compared with the control one. Both groups had the same performance levels. Students had positive perceptions of the digital escape rooms, and they believed that they were compelling and effective.

Veldkamp et al. (2020) conducted a systematic review of 39 studies that describe the design and evaluation of educational escape rooms, published between 2017 and 2019. They discuss some challenges and recommendations for developing and implementing educational escape rooms, such as aligning the game mechanics and pedagogical approaches, adapting to different settings and constraints, testing, and evaluating the escape rooms, and involving students in the design process. They conclude that escape rooms are promising and engaging learning environments that can foster various knowledge and skills in different disciplines, but they also require careful design and implementation to ensure their effectiveness and alignment with the intended goals. Fotaris and Mastoras (2022) pointed out that the major obstacle that educators face in designing their rooms is the lack of practical frameworks for such design. They propose Room2Educ8, a user-centered conceptual framework based on Design Thinking principles that provide heuristics for empathizing with learners, defining learning objectives and constraints, adding narrative, designing puzzles, briefing, and debriefing participants, prototyping and playtesting, documenting the whole process, and evaluating the escape room experience.

Taraldsen et. al. (2022) concluded based on their recent review study, that more studies are needed on the use of escape rooms for educational purposes. They conclude: "It seems that research on this topic has reached a new phase, and there is a need for structured research and transparency in the research design and methods for data collection and analysis." They further state: "We see opportunities for the use of escape rooms as a didactic tool in primary and secondary education and teacher education." We also decided to contribute our

study to the knowledge in this direction, focusing mainly on the experience of pre-service teachers with designing their educational escape rooms and their beliefs about the usefulness of the escape rooms for the classrooms.

3. Methodology

In our research, we took a qualitative approach (Creswell, 2012) because we did not want to test pre-given hypotheses, but to explore the phenomenon of creating and using online escape rooms for teaching in as much depth as possible. Specifically, we decided to use a case study. It involved 24 pre-service teachers in the first year of their university study. The research took place in one of their university courses, Software for the Modern Teacher. Participating students created their escape rooms in groups (mostly 2-3 students in each group). As all of them had mathematics or informatics in their teaching combination their escape rooms also had to focus on any of these two subjects. After completing their rooms, the students played the escape rooms of the other groups.

In our research, we focused on exploring how students worked to create their escape rooms in an online tool offered (Room Escape Maker). We were interested in what they liked or disliked about this process and how they collaborated within their group. We also sought their opinions on the use of digital escape rooms in the classroom. Specifically, we were interested in how they perceived the possibilities of using these rooms in the classroom and how engaging they could be for students. We also specifically looked at their views on the usefulness of designing educational escape rooms for the development of problem-solving as well as collaborative skills. To investigate the mentioned phenomena, we formulated 2 research questions:

Q1: How do the pre-service mathematics and informatics teachers evaluate designing their own educational online escape rooms in group work using the Room Escape Maker tool?

Q2: How do they perceive the possibilities and impacts of using educational online escape rooms in the classroom?

We used several methods to collect the data. We observed the students while they were designing the rooms and were interested in how they were doing. We also observed them while they tested the rooms created by the other groups. We also found out how they perceived the rooms created by others using evaluation cards, in which they had to evaluate what they liked or disliked about each room and what they would suggest to the authors to change. These evaluation cards also provided valuable feedback for each group to improve their room. Students' opinions on how they worked to create their escape rooms and their overall perceptions of the possibilities of using online digital escape rooms in their future teaching were also gathered using a questionnaire. Another source of data was their evaluation of this topic on their website, which they created and updated after each activity in the course.

We analyzed all the collected data qualitatively to answer our research questions. For the study of written data that we obtained through the evaluation cards and questionnaire, we used thematic analysis (Braun, Clarke, 2006). We processed the data using open coding and based on it, we identified several topics connected with our research questions. These topics students mentioned in their evaluation of designing their escape rooms in the Room Escape Maker environment and in their beliefs about the possibilities of using online escape rooms in classroom education.

4. Results

Based on the analysis of the obtained data, we identified several themes related to our research questions. In section 4.1 we will address the topics that are related to the Q1, in section 4.2 to the Q2. In section 4.3 we will focus on how students evaluated the escape rooms created by their classmates.

4.1 Evaluation of Designing Educational Escape Rooms in the Room Escape Maker Environment

In this section, we will address the themes that students pointed out in their evaluation of creating online learning rooms in the Room Escape Maker environment.

Overall evaluation of creating the escape room

Most students evaluated the creation of their escape rooms using Room Escape Maker positively, as confirmed by the responses in the questionnaire. 93.3% of students said that they liked the activity. One student even evaluated: "I froze when I had to make the room myself. But in the end, it really caught me so much that I dare to say that the process of design is even better than playing the game itself." The students perceived that the

process was fun, even though it also required some effort on their part. For example, one student stated: “Making this room was fun, but also quite challenging. It was difficult for me to come up with all the things, but when I got into it, I was already adding extra things and just confusing the kids a little bit."

Creativity in the room design process

Students especially appreciated the opportunity to use their creativity when developing their rooms. One student, e.g., stated: "I liked that I could invent what was going to be done there [in the escape room] and that I could do it my own way."

Furthermore, the students specified more in detail that they enjoyed "the process of inventing puzzles", "engaging creativity while hiding the key", and "creating various connections and mysteries". They also liked the fact that they needed to think about the player during this process. They also positively assessed that they were creating something meaningful for someone else. For example, one student commented: "I liked that I had to create a puzzle that someone would have to solve." Another student appreciated that this way she can create something meaningful for her students: "I like the overall idea of the game, that I can make it myself and use it in teaching at the same time."

Educational goals / Incorporation of educational goals

The escape rooms created by the students were supposed to be usable in classes, specifically in the subjects of mathematics or computer science. For this purpose, we recommended students read the new state educational programs for Slovakia. Several students rated the inclusion of educational goals as the most difficult part of creating their room. One student stated: "The thing that bothered me the most was such a small specification in the assignment - my escape room is supposed to develop some of the educational goals listed in the new educational programs for mathematics or computer science. Maybe the specification is not that small, ha-ha. I studied the standards for mathematics because we did this project in groups where we were mixed [subjects’ combinations]. And our common subject is mathematics. I relied on two goals [stated in the educational program] - the third and fourth - to propose problem-solving strategies and to think critically and argue". And then she added: "Although I think that these two goals are naturally reached by escape rooms".

Several other rooms aimed to develop logical thinking. Some groups also incorporated specific concepts into their room, including the use of cycles in the programming, converting between number systems, solving quadratic equations, and multiplication. However, even the students who focused on a certain concept also perceived that their escape room also developed logical thinking and problem-solving, which are important parts of mathematics or computer science. For example, one student commented: "In my ESCAPEROOM, I used arithmetic with addition and multiplication with decimal numbers. It's an activity that I also enjoyed a lot, so I can imagine that I will use it in practice as well. It develops brilliantly not only in the area of selected [mathematical] tasks but especially in logical thinking, which is the most important thing in mathematics."

Several students pointed out that it was difficult for them to add [to the escape room] their ideas for the connection [of puzzles] with mathematics or computer science, due to the limitations of the used environment. So, they had to use what they had available and adjust their original idea accordingly. In the end, however, all groups managed to come up with it successfully.

Cooperation

Almost all students evaluated that they cooperated well with their classmates when creating the escape room. What they liked most was that they could brainstorm, share ideas, and think about the whole concept together. Someone said that they could have created a more elaborate room by working together, and it was also felt that they had better ideas as a group. Another positively perceived aspect was the possibility of mutual help: "As always, when you work with someone, if you don't know something, you have someone to help you". On the contrary, they negatively assessed that the Room Escape Maker environment does not allow sharing the project between several creators, so they had to work together on one computer. However, although they would have appreciated such an opportunity to share the project in the environment, in the end, most of them concluded that they managed to work together successfully even without it.

Despite the positive perception of cooperation among most students, two students stated that they worked rather poorly in the group. One of them stated: "As an introvert, working in a group does not suit me more or less, but I am willing to make an exception." The other said: "I think it's something that is better done independently; everyone has a different idea." So, compared to other students, he did not see the difference

of ideas as something beneficial, but rather as a limitation. One student worked during the escape room design alone.

The intuitiveness of the used tool

Opinions on the intuitiveness of the Room Escape Maker environment differed significantly among students. Some evaluated that it is "quite clear and easy to navigate" and that it has "good UX [user experience]" and is "user-friendly." Others, on the contrary, perceived that it is difficult to control, and it is difficult for a new user to figure out what works and how. During the creation of the rooms at the seminar, we could observe in some groups how they try to discover individual functionalities themselves, but they do not manage to figure out how to work with them and gradually begin to succumb to frustration. In such situations, we directed them to watch the video tutorials that are accessible on the tool page. It turned out that it was not easy for students to notice that these instructions were there. Some students then stated that after looking at the instructions and "getting into it", they already worked well with this tool. One student described her progress in getting to know this tool by saying: "When I started doing it, I had quite a problem. I didn't know what to work with. I was confused by the tool. But then I managed it and fought it to a successful end."

Paid features of the tool

Several students did not like that many functions or options that would be useful to them were only in the paid version of the application. One student even commented: "The app has potential, but I don't think many people will actively use it if they have to pay to express their creativity."

Students found the locking of most graphic objects in the free version of the tool particularly restrictive. When creating their room, they had to use a relatively limited offer. They were also bothered by the fact that they could not add their links but only had to work with pre-prepared texts. However, in the end, despite these limitations, they managed to creatively use what they had available and create rooms that they were happy with. One student summed it up by saying, "I was a little surprised that most of the content was premium for the money, so our options were limited, but we still managed to create a cool room."

As another negative aspect of the free version of the tool, they perceived that it was not possible to edit the room after sending it for publication. At the time when they tested their rooms between the groups, they had already published them or sent them for publication, and thus they could not include proposals in the final version of their escape room. Some students coped with this by using the 2-day trial version of the tool, in which it was possible to make the necessary changes. Overall, however, students were quite disappointed by this fact.

Time requirements

At the same time, some students expressed the opinion that although they like the idea of online escape rooms for teaching, it is very time-consuming to create such a game. One student summed it up with the words: "I like these kinds of games and I am fond of them, so I can imagine that if someone invented them for me, then I could "play" them in class. That's why I take it as a wonderful addition to the class, but inventing and creating such a game is quite time-consuming."

4.2 Beliefs on Possibilities and Impacts of Using Educational Online Escape Rooms

In this section, we discuss the topics that students pointed out about their beliefs on the possibilities and impacts of using educational online escape rooms for teaching.

Motivation

Students find educational escape rooms motivating because they are based on learning through play. They all agreed that such playing is engaging for the pupils. They evaluated that this activity represents "fun in class" and allows "the use of the practical example or a theoretical knowledge in a playful way." They think that solving escape rooms can add variety to the lessons. One student even voiced the opinion that "Even the idea of a test in this form is something very interesting." Furthermore, students also consider solving escape rooms as a motivating way to repeat or practice certain concepts with which the pupils have already become familiar.

Development of logical and critical thinking

Many students see escape rooms as a means to develop logical thinking. For example, there was an opinion that: "Their solution fulfills not only an entertaining function, but also teaches children to cooperate and, above all, to use logical thinking and deduction."; or: "In my opinion, it is useful to use the concept of escape

rooms in teaching as well because solving puzzles or ciphers can help the students to improve their logical thinking." Someone else commented: "Children need to utilize logical thinking in a good escape game." but he went on to state: "Of course, it all depends on the focus of the given escape game." In addition, some students perceive that solving escape rooms also develops pupils' critical thinking.

Development of problem-solving skills

Students conclude that thanks to playing escape rooms, pupils can also develop their ability to solve problems. One student who in his created room focused on the goal of "analyzing problems and developing abstraction and logic," expressed his opinion: "Nowadays it is important to be able to solve problems of different levels of difficulty under pressure. At a given moment, it doesn't matter so much how much information the person has, but how he can use it." He sees the advantage of the escape rooms published on the Room Escape Maker website because the individual tasks are interesting, and the player can choose the preferred difficulty.

Cooperation

The students also evaluated that the escape rooms allow the pupils to "improve in cooperation with the classmates with whom they play the given room.". Several students considered the fact that pupils learn to work together in solving escape rooms as a key part of this activity.

Development of creativity

The students also expressed the opinion that playing escape games is a creative activity or directly stated that it develops the pupils' creativity. They often mentioned this aspect together with other characteristics associated with this activity.

4.3 Evaluation of Escape Rooms of Other Groups

Based on the analysis of the evaluation cards filled out by the students regarding the rooms created by their classmates, we identified what they appreciated the most about the created rooms, and what they perceived as ideas for improvement. We discuss our findings in detail in this section. You may find spoilers about the solutions of the individual escape rooms here, so if you are interested in playing the games, we recommend you continue reading after you try them. Together, students in all groups created a total of 9 educational escape rooms. Links to all rooms can be found here https://www.comae.sk/escape.pdf.

In Figures 1–4, we can see screenshots from the four escape rooms that the students most often rated as the best. They liked the overall handling of them and acknowledged that you could see that the writers had put a lot of effort into them.

In these, as well as in the other rooms, the students appreciated a variety of solved puzzles and the use of diverse objects. They evaluated positively if they found more objects than needed to be used and had to think which of them are necessary for solving. They also highlighted the integration of some unexpected specific items that they considered creative. For example, they liked the use of a screwdriver to remove the wooden slats under which they found the safe (Figure 1) or the need to use a magnifying glass to read the clues on the found pieces of paper (Figure 2).

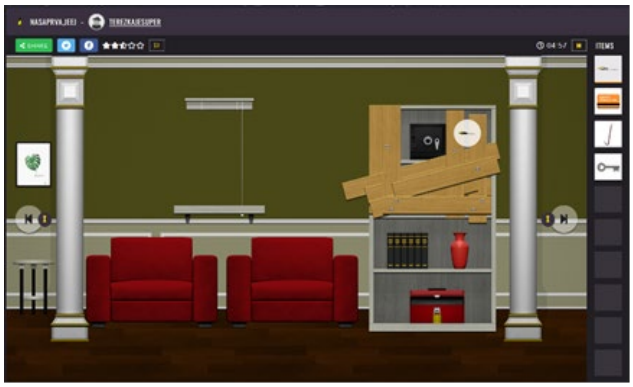

Figure 1: Room 1 https://roomescapemaker.com/u/terezkajesuper/mojaprvawau

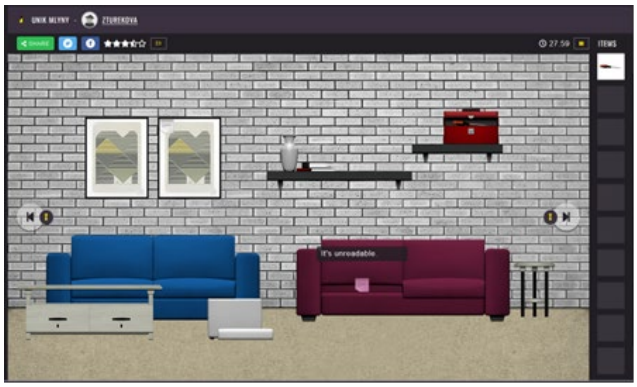

Figure 2: Room 2 https://roomescapemaker.com/u/zturekova/unikmlyny

Students also positively evaluated when mathematics or computer science was somehow interestingly involved in the classrooms. For example, in Room 3 (Figure 3) they liked the creative use of converting numbers between different number systems. In this room, to obtain one code, it was necessary to find several numbers, each of which was in a different number system, convert them to the decimal system, and add them up. On the contrary, they gave a rather negative evaluation if they felt that there were only a lot of mathematical tasks in the room and nothing else was needed except for their calculation.

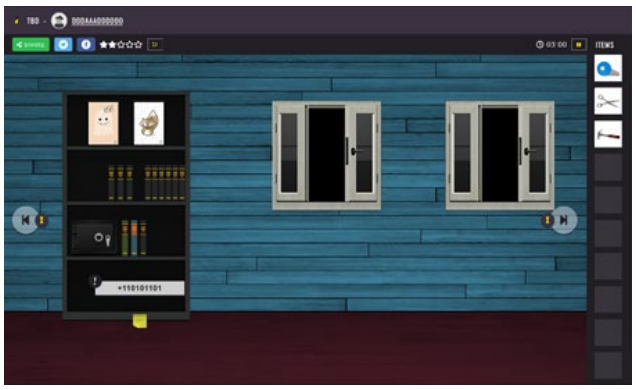

Figure 3: Room 3 https://roomescapemaker.com/u/dddaaadddooo/keksik

Furthermore, students rated positively when the rooms were more complex (Rooms 2 and 4, Figure 2 and 4). They liked it when they presented enough of a challenge for them, but at the same time, they could solve them with enough effort. On the contrary, they evaluated negatively when they were too simple or too difficult. In case they considered the room too easy, they recommended the authors add more puzzles or use more challenging puzzles. If they found the room too difficult, they recommended adding more clues.

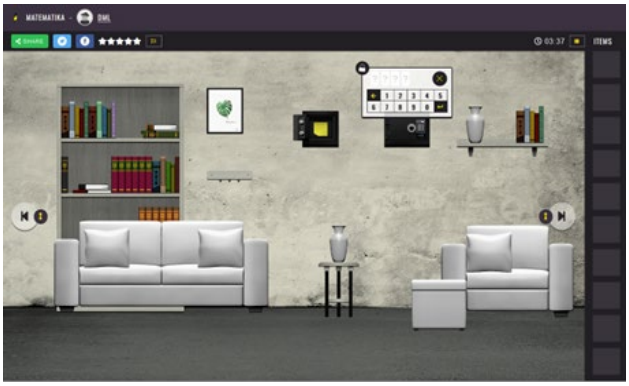

Figure 4: Room 4 https://roomescapemaker.com/u/dml/dml

If the students liked the appearance of the given room, they also appreciated its visual aspect. They evaluated negatively when something was illogically incorporated into the room's design.

The students also pointed out several small issues. Among them were wrong settings causing the items to remain in the inventory even after they were used, the ability to click on objects that could not be used, and a few minor errors in the escape room's quests. They also negatively evaluated the settings of too little time for the solving of the escape room. They pointed out that this aspect caused them to feel stressed when dealing with it.

5. Conclusion

Our article presents the findings of a study that explored pre-service teachers' evaluations of their experience designing educational escape rooms in group work using the Room Escape Maker tool. We also focused on how they perceive the possibilities and impacts of using educational online escape rooms in the classroom.

24 pre-service teachers were involved in the research, who created a total of 9 original educational escape rooms within the groups. We think the rooms the students created would be usable in the classroom after incorporating comments from their peers. However, for use by other teachers, we recommend that the students create a methodical manual for them, which would contain the educational goals of the room and the solution procedure.

In an attempt to answer our Q1, we found that students rated creating their educational escape rooms in the Escape Room Maker environment overwhelmingly positive. They especially liked the opportunity to engage their creativity and collaborate in creation with their group members. Students' opinions on the intuitiveness of Escape Room Maker varied. Some considered the tool simple, others fumbled with it in the beginning. For the further use of this tool for the creation of educational escape rooms in the preparation of pre-service teachers, we would therefore recommend first watching the video instructions available on the tool's page. However, it turns out that these instructions are not easy to discover on the site, so it may be appropriate to direct students to them directly. It also turned out to be problematic that the rooms created in the Escape Room Maker free version could no longer be edited after being sent for publication. Therefore, it would be more appropriate if the students first test each other's rooms, incorporate the received comments, and only then publish the finished room. Several students also did not like the fact that many objects and functions in this tool are only available in the paid version, which they considered as a factor limiting their design. In the future, we would therefore like to explore other environments that would be completely free or try to create such an environment ourselves. According to students' comments, this environment should also include the ability to share a project of the escape room for multiple creators.

In an attempt to answer our Q2, we found that pre-service teachers in our research sample found playing educational escape games in mathematics or computer science classes to be motivating. They perceive that this activity can develop students' logical and critical thinking, creativity, and ability to solve problems. At the same time, they pointed out that students can practice a previously learned concept in this playful way. In addition, they stated that playing in a group also develops the ability to cooperate. When they played escape rooms created by their peers, they appreciated if mathematics and computer science were meaningfully incorporated as part of the puzzles. On the contrary, they rated it negatively if it was only about e.g., solving arithmetic tasks and the room did not contain other challenges. They liked the rooms containing a variety of puzzles and requiring the use of several objects. They rated rooms that were more challenging more positively than rooms that they could solve without effort. They were also able to appreciate the nice visual appearance of the rooms. These findings can also serve as support for the further design of online educational escape rooms by students.

The limitation of this research is its small sample size, which only includes students who attended the given course at the selected faculty. In the future, it would be beneficial to involve students from different years of study and other universities, eventually not only from Slovakia.

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Microgames and Language Learning: Performance Before Competence?[1]

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Abstract: This paper reports on a study in which pairs of first-graders played microgames on small-screen handheld devices every day for 9 weeks. Its purpose was to find out whether, and if so how, adding digital games into classroom communications could 'fast-track' learning, accelerate language and literacy development, and whether it could also help bridge communication barriers for ELL learners, who may be shy, intimidated, or simply linguistically unable to interact as equals with their classmates. The "microgames" students played together were fast-paced, high engagement games that feature almost entirely one-word, verb-based instructions: "Rock", "Hide", "Pick", "Protect", and so on. Videos, fieldnotes and teacher reports note that social and linguistic interaction between children as and after they played demonstrably increased. Students' language learning appeared to be accelerated by the game's imperative to quickly decode and follow written instructions, even though many of these 6- and 7-year-olds did not yet read well enough to do that. The vocabulary which they were, in a matter of days, effectively recognizing and acting on was often far advanced from their usual first grade language arts lexicon, with words like "disguise", "hypnotize", "escape" and so on, presumed and treated, from a curricular standpoint, as exceeding their linguistic competence. Equally noteworthy was the technical competence the children displayed in mastering game controls, along with an array of different game mechanics. Using video documentation throughout the study provided both empirical evidence and persuasive examples of how playful interaction with more capable peers can support linguistic development as well as, or even more effectively than, conventional language curriculum and instruction, suggesting that when learning is scaffolded by play, our reach can so often exceed our grasp.

Keywords: Microgames, Language learning, Primary learners, Learning ecologies, English language learners

1. Introduction

The study took place in a first-grade classroom, in a small (under 400 students) ethnolinguistically diverse public elementary school located in a suburban (until recently, rural) area 25 minutes outside a major Canadian city. About a third of the class participating in the project have first languages other than English, with 5 students identified (by their parents and the school's learning support team) as "ELL"—English Language Learners, at varying levels of English language mastery, with some students just beginning to express themselves in English, and others demonstrating near fluency. Their teacher, Ms. B, has taught for 12 years, with the last 6 being at this same school, where she has taught kindergarten to grade 2. The game played was designed to have mass market appeal, rather than a specialized 'educational' game. *Wario: Get it Together* for the Nintendo Switch is an entertaining commercial-off-the-shelf party game that features mostly one-word commands, and timed micro-game play. Students played in teams sharing a designated Switch with a partner, over 9 weeks for 15 minutes a day, followed by a 5-minute 'debrief' with their classroom teacher.

1.1 Studying Game-Based Learning Ecologically, a Note on Methodology

We have seen across several previous game-based learning studies, Authors (2017;18) that notwithstanding findings of clear and evident advances in student learning, we can't conclusively say what proportion of these positive changes came about through gameplay rather than other concurrent factors, such as teacher questions, peer relationships, technology, 'climate' and classroom activities, all of which may very likely have impacted that result. We can't say because we don't know, and we don't know because we mostly haven't looked. Learning through playing digital games is hard to study and even more difficult to measure, because it doesn't often take the form of "learning" as we've known and come to recognize it. Another challenge in providing evidence of game-based learning is that the criteria by which teachers are required to assess, and the terms in which they need to report, student learning are based on traditional monological tools and practices, which do not readily

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map onto or align with the dialogical, interactive structure of digital game-based learning tools and practices. (authors, 2017)

This study was designed to learn more about the interactive structure of game-based learning tools and practices, by digging deeper into the larger system of relations within which gameplay is positioned. We aim to situate our research findings about students' game-based learning 'ecologically', which means finding ways to study gameplay within the larger ('macro-media') ecology of the classroom, a network that includes institutional roles, responsibilities and 'ruling relations', teachers, classmates, and the researcher, both face-to-face and virtually, into which a new 'micro' media ecology of the handheld console game is introduced.

Working in classrooms with young children, and using multimodal media, introduces extensive considerations around research ethics, especially where ubiquitous audio and visual data are used, as they must be in a study of this kind. We ensured all parental and teacher permissions, and all student "assent" processes, were based on fully informed consent, and this study was reviewed and approved by both the school district and the several universities from which the research team was drawn.

1.2 Methods and Data Sources

Using a combination of two (fixed) GoPro cameras and one teacher-operated ('roving') iPhone camera provided an audiovisual record of both student play and teacher-led debriefs that could be triangulated to allow a physical description and record of elements like uses of space, movement, uses of tools, and physical and verbal interactions. Designating devices by team and tracking the (few) early changes the classroom teacher made provided information on student/team composition, and game progression by each team was recorded at intervals throughout the study. Student drawings were collected throughout, and classroom records and teacher resources and requirements for grade 1 language and literacy development, including reading lists used and teacher assessments of children's changing reading levels were compiled. Photos of the classroom, the images and information on its walls, and images and videos of students as they played in class and in the playground, as well as short, videotaped interviews with individual children, added to our sources of information about how the project rolled out in "lived actuality". Using an online form posing a set of questions about each week's experiences helped track teacher reflections and observations. Researcher fieldnotes were based on viewing the media materials for weekly play and debrief sessions, and, less often, on being physically present to provide tech or other support. Fieldnotes were completed by both researchers, and shared with the classroom teacher. To elicit individual samples of students' speech, a 'pre-program' activity asked children to explain how to make a paper heart, and their individual responses were video recorded. A "post-program" activity asked children to explain how to play a "microgame' they had played, and their individual responses again recorded.

Through these means we compiled and collated a rich and diverse trove of material on the possible impacts on how 'simply playing' an unrepentantly 'fun' game might promote and even accelerate students' language and literacy development, and build communicative bridges for ELL learners who while having the greatest need for communicative interaction typically engage in it the least. The challenge is of course how to analyze such a wealth of documentation, and that is not something that can be adequately undertaken at this point. This paper will instead concentrate on 4 key 'events' in hopes of illustrating, by the end, how play performs its educational work.

2. "Pre-Play", The Heart Activity

For this study, we wanted to devise a **pre-assessment** of each child's language/literacy capabilities, one that could be easily carried out by the teacher, in order to preserve the classroom environment, and minimize researcher disruption. A specific educational objective was to contribute to developing students' communicative abilities, using gameplay to break down social and linguistic barriers to interaction between fluent English language speakers (ELS) and ELL learners. So we needed a baseline against which to identify change. As a way to gain some indication of each child's communicative abilities prior to their 9 weeks of digital game-based interactions, we used an "everyday communication" activity, in which students are taught a skill, then asked to explain it to others, orally for younger students, or in writing for older ones. The skill, selected by the classroom teacher to align with curriculum goals, could be how to bake cookies, how to fold a paper crane—anything that conforms to the minimal requirement of learning a skill, then communicating how it's done.

Transcribing and viewing the children's videotaped responses provided one basis (among many) for assessing the children's language/literacy development—an indication, or an impression, more than a formal assessment, based as it is on a small sample of students' communicative abilities. To guide and align assessment criteria among the project team of classroom teacher, research assistant, and principal researcher, we first tried out 5

simple criteria: correctness, fluency, detail, and ease and effectiveness of communication. Using transcriptions and videos, up to 5 points were assigned for each criterion, for a total value out of 25. On that basis, each member of the team separately carried out an assessment of each student's abilities to explain how to make a paper heart. Then we met to share experiences and results, and to compare notes. Since this was a pilot study, we particularly wanted to see whether this 5-point analytical framework might prove a useful tool that could be redeployed at the end of this study to tell us whether and how our game-playing first graders' communicative abilities may have changed over the course of 9 weeks of gameplay. Through discussion, we identified conceptual overlaps and ambiguities, modified the initial criteria to include 'explicitness' then performed a re-analysis of the same material. The initial assessments and the subsequent re-analyses are shown below. Yellow indicates that the student is an English Language Learner (ELL), and the letter shown for each student indicates their school-designated levels: e for "emerging", d for "developing", c for "consolidating". Asterisks indicate that the students used materials (pencil, paper, scissors) and/or gestures rather than words to explain how a paper heart is made.

The table below illustrates the assessment criteria used, noting the duration of each student's recorded interaction as they responded to prompts to 'tell me how to make a paper heart'. This table shows the principal researcher's (PR) scoring; the same assessment was carried out by the Research Assistant (RA) and the classroom teacher (CT).

	Name	Duration	Correctness	Fluency	Detail/ explicitness	Ease	Effectiveness	Score/25
1.	M1 (d)	.19	2.5	2.5	2.5	4	3	14.5**
2.	F1 (e)	.14	2	1.5	1	2	0	6.5
3.	M2 (e)	.22	2	2	1.5	1	1	7.5
4.	M3	.44	4.5	4	4.5	1	3	17*
5.	M4	.33	4.	5	4.5	5	4.5	23*
6.	F2	.23	4.5	4	4.5	4	3.5	19.5
7.	F3	.28	3.5	4	3.5	4	3.5	18.5
8.	F4	.17	4	4.5	3	4.5	3.5	19.5*
9.	M5	.34	2.5	3	3	4	2	14.5*
10.	F5	:25	2.5	3	3	3	2	13.5
11.	F6	1.31	4.5	5	5	5	5	25*
12.	M6	1.29	4	3	5	3	4	19*
13.	M7	.30	4	5	4	5	4	22*
14.	F7	.28	3.5	4	3.5	4	3	18*
15.	F8 (d)	.24	2.5	2.	1	3	2.	10*
16.	M8	1.21	4	4	2	4.5	4	18.5**
17.	F9	1.12	3	4	2	4	3	15*
18.	F10 (c)	.52	2	3	3	3	3	14*

These speech samples were re-analyzed at the end of the study (to provide enough "breathing space" for the researchers to take a fresh look) using the slightly revised criteria arrived at after reviewing our initial heart activity assessments. Shown below are both the initial and the re-analysis total scores, and the average score among all three coders. Significant changes in the second round of analysis were that the PR's scores for both ELL and ELS students were lowered, as the PR (not a teacher) learned from discussions with the CT and RA (who was also a teacher) how to interpret the language samples more accurately. Interestingly, the classroom teacher's average scores for ELL students shifted significantly upwards by nearly 3 points using the revised assessment criteria to which "explicitness" had been added.

The class average duration of the answer is 39 seconds, but note the sizeable difference in speech duration between ELL learners (5) and non-ELL learners (13), several of whom speak one or more languages other than English: 46 seconds for ELSs; 26 seconds for ELLs.

Initial heart activity assessment:	
PR ELL Score= 12.05	PI ELS Score= 21.6
RA ELL Score= 10.8	RA ELS Score= 18.9
CT ELL Score= 8.	CT ELS Score= 16.5
Averaged ELL assessment: 10.28	Averaged ELS assessment: 19.

Heart activity re-assessment	
PR ELL Score#2=10.5	ELS Score=18.7
RA ELL Score#2= 11.4	ELS Score= 18.9
CT ELL Score#2= 10.7	ELS Score= 16.5
Averaged ELL Assessment: 10.86	Averaged ELS Assessment: 18

Keeping in mind that these are at best only impressions garnered in an initial attempt to create a rudimentary assessment framework, it is worth noting that while the classroom teacher's scores were lower than the RA's and the PR's for both ELL and ELS groups, all three independently scored the ELS students as almost twice as competent communicators as the ELL students. Comparing these rough and ready assessment attempts with the classroom teacher's regular, ongoing assessment of students' reading levels, one month prior to this study, revealed an even greater gap: ELL students averaged a 3.3 reading level while ELS students averaged 8.7. That gave us 'baseline indicators' we could return to at the end of the study to look for changes, both in the class as a whole and in the *relative* progression of English language learners and English language speakers as digital games became a part of their school schedule.

3. Wariowords

Would playing this single-word game impact these first graders' language development and would interaction with classmates by a less fluent speaker of English be enabled by a linguistically 'stripped down' game? Would they be able to build lexical bridges with their classmates through a shared game-language?

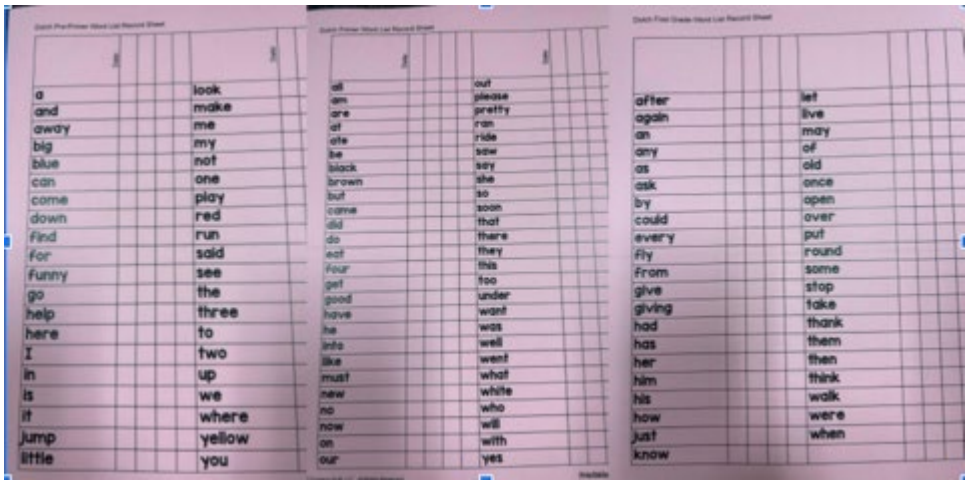
The game lexicon players are exposed to, and to which they must respond correctly by means of a time limited pre-determined symbolic action manually executed, constitutes its non-negotiable 'rules of play'. These rules of play are imposed by the game system on its human users and interactants. Through play, students will encounter and try to respond meaningfully to these words, which are also voiced as they are displayed. They are noticeably different from the words that make up the widely used word lists, principally Dolch lists, that help classroom teachers guide and track their students' language and literacy development. The game lexicon includes three categories: (1) *"Command words":* a term or set of terms conveying a command, which is the game-task instruction. These words are also called out, though the user controls on/off and volume functions and need not necessarily hear the words spoken; (2) *Cross-game words*: terms designating generic game structures and functions that apply to all the minigames like "level up" or "boss stage", and (3) *Action descriptions*: a set of words displayed in nondescript size and font, like "jump" or "attack". Some actions are less often used, and some, like "boomerang" or "shoot a yoyo" are specific to one of the game's 18 different characters, each having different abilities or 'superpowers' to act in/on the game in defined ways—shoot a beam, blow up by contact, etc.

This first phase of the study focused on "Command Words", a term devised to encompass, compile and track all the game-task instructions these students would encounter through play. The first game command words include *Hypnotize, Take off, Light up, Steal, Get him, Draw, Collect, Protect, and Topple*, with the microgames changing rapidly. The students' uptake of "command words" is of special interest because acquiring a reliable ability to decode the game screen is a non-negotiable condition of playing. We wanted to see how their language might develop alongside their game progression. We created a command word list for each of the first 8 games, and a wall chart with each game's word list along one side, and a column with each child's initials along the top,

the idea being to invite children to add a star in their column for the new words they learned as they progressed through each minigame.

Some children were eager, some compliant, some entirely shunned the whole thing, and some possibly just answered randomly—the idea here was just to find multiple ways for the children to interact with the words they were being exposed to under the "microgames" conditions of timed recognition and response.

Then we compared the number and complexity of the game vocabulary that these game-playing first-graders had acquired and used and recognized, with the classroom word list the teacher was already using for first grade. Displayed on the wall in her class, Ms. B. has a Dolch word list, an early language learning resource extensively in use by teachers. Ms. B. uses words drawn from the Dolch pre-primer list to track her students' reading levels. Devised originally in 1938 based on the frequency of their occurrence in children's books, Dolch word lists are internationally relied upon for tracking students' reading development, and look like this:

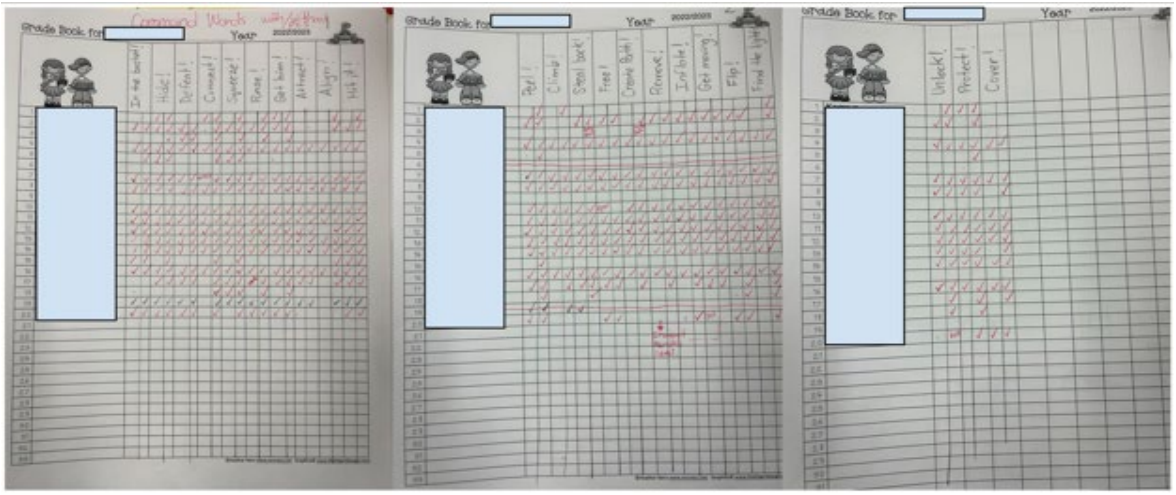


These are assessments in which the teacher sits down with each student and goes through a wordlist, tracking the growth of their 'sight word' reading vocabulary. These are completed at different times, and over the span of the school year. At the start of our study, Ms. B. had compiled information on her students' progress in learning to read this set of Dolch words and, as noted above, class reading levels recorded in the month before the study began showed ELLs averaging a 3.3 reading level while ELS students averaged 8.7.

3.1 Dolch Words and Wariowords

To create a comparable record of students' growing game vocabulary, Ms. B. carried out a parallel assessment, using 23 of the game's command words. Her checklist, completed between April 24- 28th and shared below, shows which words the students were able to read. The first column shows each student's recognition of the word presented as "plain text", (black letters on white background) and the second shows recognition of the same command word presented in the game screen. Note how many more of the words children were able to

decode when given the whole image (304) than when given plain text (247)—a 23% increase in correct responses.



4. Drawing on Play: Representing Characters and Mapping Story

One of the "Big Ideas" in the first grade curriculum is that "Stories and other texts can be shared through pictures and words". When children were asked to draw a picture of their favourite character, and to write about why they liked that character, everyone, including students who usually do not enjoy drawing, fully engaged in this activity, despite differences in fine motor skills, and the amount of detail in their drawings. Exploring and representing character through a game is a different experience than exploring a character through reading, because the player acts on behalf of the character, and the character's goal becomes the player's goal. The children loved these characters and all of them had a favourite and could explain why they liked them. Most of the girls chose a female character as their favourite. In the beginning level the only female character is Mona, who rides a scooter and throws a boomerang. Students could explain that they liked 9-Volt because he shoots a yoyo, Red because he drops bombs, Ashley because she flies, and Dribble "because he is powerful". One student wrote that they like Dribble because he shoots but, "Sometims I finb it hrd cas he oley dos it wanway".

There were three 'developmental indicators' students drawings displayed: 1. colour, 2. detail, and 3. using the whole 'canvas'. Ms. B. mentioned a standard expectation at first grade was the use of at 5 colours, noting these game-based drawings were far more **colourful** than most of the students' drawings had been—a first expectation met. They were, as well, much more **detailed** than previous drawings, representing scale, perspective, activity, and movement, accomplishing the second curricular criterion. Inviting students to represent a "command word" not just as text, but as displayed in the context of the game, led directly to students representing characters within their own distinctive gamescreens. This meant paying close attention to context, detail, and the game's central mechanic/movement. The game they played maximized meaningful **use of the entire space**, which is what they proceeded to imitate, and in this way, every student attained a third 'developmental indicator' of competence.

Taking students beyond characters, characteristics, and powers, the last objective pursued through drawing was to help them pay attention to the game's story, to contextualize the levels they were playing within the narrative

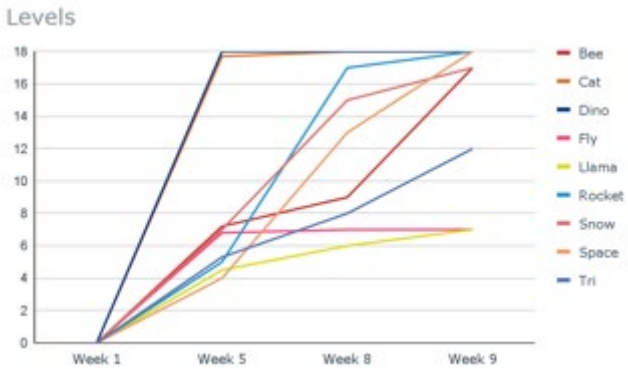
frame of the game as a whole. This was a way to explore 'setting', in Language Arts, and to work on a grade one Social Studies curricular competency, where students are expected to be able to examine different perspectives on people, places, issues, or events in their lives. Ms. B. first created an outline of the map of levels so that students could create a travelogue of where they had been and where they had left to go in the game before they completed all the levels. The children were heavily invested in filling in their maps by drawing the locations of the character's domain within the game, using their Switch consoles to look at the game map and the characters and objects associated with the specific locations (levels) on the maps. Extremely proud of their work, students would often ask to work on their maps, and would do so in their free time as well. They also created a collaborative class map of the game, which was posted on the wall throughout the study.

5. "Post-Play": Tracking Changes

At the conclusion of the gameplay program, students' game progression was recorded, along with their progress in learning new words, as measured by the number of stars they added to their Wariowords wall chart. Their maps and drawings were compiled for review (not reported here), and students were again individually assessed based on how well they could communicate how to play a microgame of their choice. To track game progression, students had been assigned to play in pairs, with team names based on distinguishing stickers on the back of each Nintendo Switch console. When tracking student play progress, each level was noted by their acquisition of a character, listed as levels 1-18 for each character that joined the team. The game is completed when all eighteen characters join Wario's team. These characters were referenced in student discussion and artwork, both throughout and beyond the duration of the study.

5.1 Gameplay Progression

In order to track student play progression over time, at three different weeks in the study we marked how many characters had been acquired. The figure below shows the play progression over the nine weeks of the study, marked at five weeks' play, eight weeks' and the final week.



Especially notable is the speed with which 2 of the teams completed all 18 levels, the fact that ALL teams made progress, and the fact that, of the two 'lowest' teams, one team, both girls, had one of the class's most experienced video game players, who was also one of its top students, paired up with a relatively novice ELL student. They enjoyed their play together, reached a level they liked playing, and opted for familiarity and repetition rather than progression. This was a surprising result, and contrasted with the progression of an equally very experienced girl who was teamed with a (quite advanced) ELL boy with negligible video game experience—that team was one of the two reaching completion the fastest. We haven't yet delved into the analysis of game progression results, and simply report these here.

5.2 Better Communicators?

Using the framework we had developed initially for pre-assessing students' communicative competence in the heart activity, we applied the same criteria to a "post-program" analysis of children's explanations of how to play. By no means a comprehensive speech assessment, the framework was designed to broadly characterize students' everyday communicative abilities, to gain an ecologically valid picture of students' expressive competence. Their teacher conducted the informal assessment, asking each student about their favourite minigame within WarioWare, and how they might tell someone else to complete the same task within the game, following the same protocol as the pre-assessment by asking the participants to describe the steps in making a paper heart. Students could select any minigame they'd played, describe what they liked about it, how they figured out the solution to playing it and winning, and how they might tell someone how to complete it. The assessments were conducted individually, within the classroom, and in each recorded assessment other students could be heard in the background. While there is more data analysis to do, we found that as a class, students held longer conversations, used more complex language, and used more detail to describe the minigames they played, than they had in their heart activity accounts. Each post-assessment video was at minimum close to twice as long as the pre-assessment video, understandably, since the explanatory task was more complex, and the students had no explicit instructions for playing the minigames, as they did have, along with teacher-modelling, of how to make a paper heart.In the pre-play heart activity, the duration of ELL students' explanations averaged 26 seconds, nearly half as long as the heart activity recording for the ELS students, who averaged 47 seconds in the post-play "how to play" explanations. Unexpectedly however, ELL students this time around averaged closer to twice as long at 5.26 minutes as their ELS classmates, at 3.03

Using the same assessment framework as in the heart activity assessments, the greatest improvements in fluency and ease and effectiveness of communication were made by the ELL students, who (averaging the scores of the three assessors) improved from 10.86 to 12.9, with the ELS students showed only a fractional increase from 18 to 18.3. Beyond literacy assessments and vocabulary counts, the confidence with which participants discussed their play was characterized as dramatically higher by their teacher, and every child succeeded at learning gameplay and progressing through the game. Every student produced both individual and whole-class drawings, mastered a digital device with ease and fluency, and expanded their interpersonal experiences, skills and relationships within the classroom. Students could be heard using gameplay language and command words in everyday conversation, as well as in the playground, demonstrating the impact of gameplay environments beyond the classroom. These communicative accomplishments are not restricted to language, as seen subsequently in the children's playground activities, in their art and free time activities, their understanding of game mechanics and in the overall comradery of the classroom.

6. Just Playing

A significant and surprising "absent presence" in game-based learning research has been any interest in studying the educational value of *just playing*, in taking playing seriously as a foundational element in learning and development. In this pilot project "just playing" was the object of study, and all the play sessions, except for a few at the start as we ironed out technical challenges, were videorecorded. There was no instruction going on, no 'discipline' was needed, there was little to no direction, and nothing students had to other than "just play" for 15 minutes. Just under 20 hours of gameplay time was logged and reviewed, and fieldnotes written for every play session.

What we saw was that playing effected considerable shifts in the learning ecology. Children's use of **classroom space** changed over time, beginning with a dispersal away from the usual learning areas—the large, alphabet-design rug, where each child sat quite close together on a single "letter", and the shared tables and chairs where they did their classwork. Instead, dyads and small groups would huddle over their Switches, and look over each other's shoulders, and pass them back and forth in corners, around the perimeter of the classroom. There was no 'off-task' behaviour and no need for the teacher to urge or remind or direct, and there were no constraints on student movement within the classroom space. The movement data captured in the full set of videos needs yet to be analyzed, however what appears is a limited return to those evacuated centralized spaces by the end of the project. In terms of **children's physical proximity** during play, which again merits further exploration, we saw almost no aggression, no misuse of the technology, and remarkable closeness, including "snuggling up" while playing, or just leaning against one another looking at a handheld screen—as if in genuine friendship, or as if they might be siblings, without the rivalry**. Affectively,** facial expressions and bodily positions displayed pleasure, relaxation, excitement, intense attention, and of course some frustration—but not much. For while there was plenty of intense disappointment at timing out or otherwise messing up, this is a game in which things move too quickly to hold on to disappointment for long, and so the emotional climate was both exciting and, in another way, peaceful. Everyone got along. This result has particular importance for the post-covid generation of early learners who have missed out on the kinds of socialization they need to manage school. Interestingly enough, these foundational social skills of building relationships, joint attentional activity, collaboration and mutual support, sharing and taking care of resources, and making new friends, would appear to have been dramatically advanced in just two months—simply by playing a game! And everyone chatted. Because authority was distributed, **language** was, too. More children talked more of the time, and at the same time across the dyads and small groups. Simply, there was more 'space' for more voices, and this ought to have been of greatest benefit to the children who we found (not surprisingly) spoke the least. This dynamic also created more (and 'safer', because its all "just play") opportunities for other children who able to participate in dialogue, but who don't speak often. In her week 3 notes, the classroom teacher observed *"The kids who are often quiet are animated, more talkative and laughing out loud while they play."* The class as a whole shared, in a remarkably short space of time, a **common language**: a vocabulary that included an extensive number of fairly advanced "command words", as well as language of game technology, of controllers and controls, of mechanics, and of game design elements (like characters and powers and maps) that ought to transfer well to their future learning.

In these and other ways, it's possible to see how the competencies of individual children can be built up or stripped away by classroom practices. Games can provide, and this game did provide for these children, a "socio—technical" ecology that helps scaffold performance. In our final interviews with the children, they were unable to explain the 'competencies' underlying successful gameplay—and maybe that's because gameplay knowledge is just not that kind of knowledge. But many of the children could and did talk about how to scaffold successful performance: "try again, hit the eye, ring the bell, just try again, ask if you want me to show you how to play, or if you want to play it and I can help you…" Whether or not competence actually results in good performance just might depend a LOT on the kinds of experiences, and the kinds of support, "just playing" affords in a classroom.

7. Conclusion: What Games can do for you!

In-game learning is inextricably bound up with action, both bodily, (real-world controller actions), and virtual (scripted sequences responding to controller input that directs game-world actions). What that intimate connection with player activity means, importantly for educators, is that degrees and kinds of understanding multiply. In this game for example, players can succeed at an activity by: reading/recognizing the word in print; by hearing and comprehending the word spoken in the games audio track; by recognizing the image within which the word appears, or by salient visual elements within the game screen (a turntable, a curtain, a watering can); by imitating a classmate's play; or by looking at a Youtube video and following the actions represented. Understanding game-based learning's intimate connection with player activity means recognizing that language, more precisely langua*ging*, human communication, is multimodal and multisensorial.

It means, too, that we can pedagogically recognize how comprehension changes and evolves, and that development over time happens when you are enabled to continue in an activity even if you are just beginning to grasp it, so long as you can succeed at playing well enough to "stay in the game" long enough to discern more of what is being communicated, and to develop ever-enlarging abilities to communicate reciprocally. There are far fewer ways of being wrong when there are multiple ways of being right, which is what this game-based, activity-driven language and literacy project made possible. And that suggests educators will gain by acknowledging and building on the diversity of ways children **can** succeed, even if that means taking different

pathways, and using different tools and methods to get there, instead of focusing on establishing their individual 'competencies'. It might then be possible to pursue the success of every child more than their academic ranking, to concern ourselves less with assessing children's competence relative to homogenized testing and instead invest pedagogical energies into scaffolding their successful performance. We might then better appreciate how great can be the contribution of the classroom community, learning technologies, and the environment to every child's abilities to both develop and display their learning.

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Science4Exit Project: Experimental Escape Games With Digital Enrichment in an Extracurricular Learning Venue

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Abstract: Exit games, escape games or escape rooms are innovative formats for teaching chemistry and for learning and applying scientific content. In the project "Science4Exit" experimental escape games with digital enrichment are developed, tested and evaluated. They will be carried out in the teaching and learning laboratory of chemistry at the University of Education in Weingarten. One of the project's goals is to increase pupil's motivation for science topics and interest in STEM subjects, as well as to improve the application of knowledge acquired in school. It also promotes 21st century skills (creativity, collaboration, communication, critical thinking and problem-solving) by embedding them in a game-based context. When playing escape games in the chemistry teaching and learning laboratory Ex³lab, experimental ways of knowing and solving are essential to reach the goal. As in classical or combinatorial puzzles, the result of an experiment is needed to unlock the next challenge. Escape games are partly digitally guided (e.g. by Actionbound, H5P) or digitally enriched with different technologies as needed (AR, explanatory videos, etc.). The Escape Games developed are used so that pupils can deal with scientific content in a playful and experimental way during a visit to the teaching and learning laboratory. They are supervised by student teachers as part of their studies. An escape game on energy supply and climate protection as well as building blocks for further developed escape games are presented below.

Keywords: Escape-room, Exit-game, Chemistry, STEM, Digitalization

1. Introduction

Escape games have grown in importance in recent years and have become a popular learning format. The playful approach of escape games, also known as gamification, has helped to increase pupils' interest in general topics (Tercanli, Martina and Ferreira Dias, 2021). The project Science4Exit uses this approach to increase pupils' interest in chemistry content through a game-based approach. Although game-based learning usually takes place in digital formats, this approach and this project emphasise the importance of combining hands-on experimentation and digital engagement with science content. The implementation is realized through escape games enriched with digital and experimental components.

In addition, the student teachers can gain practical experience in the context of supervising and accompanying the pupils and strengthen their competences in terms of teacher professionalisation. As the project progresses, the pupils themselves become active players and are involved in the design of further Escape Games.

In the following, a short introduction in game-based learning is given and specified by the application in natural science teaching. Subsequently, the project Science4Exit is presented as specific application example.

2. Gamification and Game-Based-Learning

According to Deterding et al. (2011), gamification embeds design elements from games in contexts that initially have a more serious background and are not playful This is often seen in everyday life through various intersections with gamification, such as when language learning apps use game elements to encourage users to continue learning content. Elements such as level systems, time pressure, narratives, avatars, points, teamwork, and competition are commonly cited (Reeves and Read, 2009). With respect to constructivist learning, the reverse – the "de-gamification" of a game – can be observed. It involves using elements, properties, or a whole game to deconstruct it and make it reusable for a new or different game with the purpose of creating a motivating learning environment. Game elements such as points or badges are used to increase the attractiveness of the activity and to motivate pupils towards goals that are not only for entertainment or commercial purposes. The term "gamification" initially originated in marketing, where the primary goal was to activate potential customers to buy a product or use an app (Kim *et al*., 2018; Le Lay *et al*., 2021). With regard to educational processes, the term was first used in 2002 (Sailer, 2016). As our society continuous to change through factors such as globalization and digitalization, the way we learn is also changing. Playful content has proven to be an attractive way to convey knowledge through this motivational approach and is increasingly being implemented in various fields of application. Due to the rapid development of digital and social media,

there is a promising opportunity to extend gamification to the education sector (Aubeux *et al*., 2020; Goethe, 2019; Strahringer and Leyh, 2017; Kauffeld & Kettler, 2019; Kim *et al*., 2018; Sailer, 2016; Shute, Rahimi and Smith, 2019; Teclani, Martina & Ferreira Dias, 2021). The pedagogical approach of game-based learning uses games as a medium. These games contain systems of symbols and rules that enable pupils to interact with each other and with the game in order to achieve certain goals. Unlike mere play, rule-based games have their own game world that is distinct from everyday life. The use of narration and scenarios can stimulate the imagination of the players and enhance the immersive experience (Kettler and Kauffeld, 2019).

The process of playing occurs cyclical. In the first step, pupils receive academic input from teaching content. When applied to the topic of escape games, learners first receive preparatory material for the game in order to realize the input. This may include repetition of content covered in school or designed input, such as the processing of content through an explanatory video or worksheets that convey extracurricular subject matter. The characteristics of the game are then explained immediately before the start of the game. In the first sequence of the game, learners evaluate the input and act accordingly in the first challenges of the escape game. This may include the initial puzzle or experiment. If no action is taken due to missing information or prior knowledge, learners are supported appropriately by the tutors. Once the first challenge is completed, the players receive feedback from the game on the results of their actions, which then serves as the basis for the next action. This cycle continues until the escape game is successfully completed. In summary, game-based learning, as an active form of learning, is defined by solving puzzles and ultimately challenges (Schwan, 2006). It is important that tasks and problems reflect reality in order to promote learners' problem-solving skills and avoid the creation of inert knowledge. Therefore, the game scenario should be as close as possible to the real-world application scenarios of the subject matter in order to facilitate the retrieval of knowledge in real-world application situations (Kettler and Kauffeld, 2019). The concept of game-based learning offers a wide range of applications. These range from simple drill-and-practice games that serve to increase motivation in repetitive learning tasks, to the conveyance of complex theoretical relationships in simulation games. The use of digital technologies is not mandatory, but they are often a useful addition to the design and implementation of escape games.

3. Escape Games In The Context of the Natural Science Teaching and Learning Lab EX^3-LAB

Science teaching and learning labs typically constitute constructivist learning environments based on their objectives. Constructivist learning environments are defined to provide the possibility of an increased interactivity between the learner and the learning environment. The learner is asked to explore and interact with the environment and learning is hence a process or an activity and not a result (e.g., Anzai & Simon, 1979; Twomey & Perry, 1996).

Through these features, constructivist learning environments are thought to promote the so-called 4 Cs to a particular degree (see Figure 1; Brägger *et al*., 2021; González-Pérez and Ramírez-Montoya, 2022; Oelker, 2022):

- Critical thinking and problem solving
- Communication
- Collaboration
- Creativity and innovation

Figure 1: The 4K competences according to the 4K Model (own figure)

Science learning labs are run by departments of subject didactics at universities and not only cater for pupils but also involve teacher training students in the supervision and operation of the lab (Euler and Schüttler, 2020; Hempelmann and Kratzer, 2019). In the context of subject didactic courses, students are given the opportunity

to design teaching materials for school classes and then test their skills by supervising and supporting pupils in the lab. This provides a protected space for the teacher training students to strengthen their skills while ensuring appropriate supervision of the pupils (Haupt *et al.*, 2013). Supervision in small learning groups, known as microteaching in academic teaching, ensures targeted supervision and intensive instruction of students. This specialized form of teaching and learning setting allows learners to improve their pedagogical skills by focusing on a narrowly defined topic area and concentrating on specific teaching methods such as instructing, observing, and supporting (Sorge et al., 2020). This form of learning is also beneficial and motivating for pupils as it provides an extracurricular, specialized form of subject-specific deepening in small, intensive learning groups.

In the context of the COVID-19 pandemic and digital transformation, student learning is changing both in school contexts and in individual out-of-school learning processes. Of particular note are the sales figures for puzzle and brain games, which are experiencing a significant increase in popularity (Statista, 2021). In the recent years, digital games and simulations have opened up for teaching and have since increasingly gained the interest of all actors participating in the education system (Selander *et al*., 2019) and have hence seen as a possibility to enrich teaching and learning laboratorys. Especially escape games seem to represent an emerging trend (Bell, 2018). Escape games bridge the gap between puzzle games and impressive scenarios in which the puzzles are located (Vergne, Simmons and Bowen, 2019). For example, in one of the escape games we have developed, pupils are faced with the task of having landed in space and having to find a safe way back to Earth. A key aspect of classic commercial escape rooms is that the participants are locked in as a small group of three to seven people and can only escape by solving the various puzzles found within (Dietrich, 2018). For safety reasons, this concept cannot be implemented analogously in the setting of a teaching and learning laboratory. As a result, escape games are developed that consider all of the desired facets that can be carried out within the requirements of the teaching and learning laboratory. When designing the puzzles, it is essential to tailor them to the target audience in order to prevent cognitive exhaustion and the associated failure in the room (Nicholson, 2016).

Multiperspectively, the model of the 4 Cs (see Figure 1) can be applied to the level of participants and creators of an escape game. In the game, players learn to think, learn, and act for themselves by solving puzzles and, in the chemical context, experiments (critical thinking and problem-solving). It is essential that learners engage constructively with the subject matter and solve problems as a team while not marginalizing personal, social, and communicative competencies (collaboration and communication). In the authentic learning situation, they are equally challenged to take risks and find creative solutions and ways to solve the puzzles (creativity and innovation) (Brägger *et al*., 2021). Similarly, the 4C model can be applied to students as creators. For example, in the seminar "Chemical Research Project," students cooperatively create building blocks for new escape games, pilot and evaluate them (cooperation). In the development process, they are in constant dialogue as a team (communication) to implement their respective topics or socially relevant themes reflected in the escape games (critical thinking). To avoid monotony in the game, creative and varied puzzles and exciting stories and ideas must also be implemented (creativity) (Banerji, Brott and Serwene., 2021).

Like commercial or recreational escape games, educational escape games combine practical and cognitive activities and thus appear particularly attractive as an opening form for learning settings because a free space for mistakes is provided during learning (Veldkamp *et al*., 2020). As a result, there is direct feedback for pupils' learning. This is achieved through a simple game loop of the escape games. In this loop, learners are given the challenge or puzzle/experiment to solve, and then receive a reward. These usually represent the next challenge or completion of the escape game (Wiemker, Elumir and Clare, 2015).

4. THE Project Science4Exit

In the project Science4Exit, gamification is applied in two ways: for the students who learn by creating escape games and for the pupils who use them in a traditional sense. The goal of the project is to develop, test, and evaluate experimental escape games with digital enhancements.

The gamified structure aims to promote interest in STEM subjects, especially in the field of Chemistry among pupils. In recent years, the number of pupils choosing chemistry-related study courses declined, while the demand for chemistry-related jobs has increased (Archer et al., 2022; Ulber, 2021). Among the reasons cited by Archer and colleagues (2022) are declining interest and low self-efficacy. By embedding classical topics of chemistry education in a playful manner, interest and self-efficacy can be increased. In the Science4Exit project, one of the ways to gain knowledge is through experimentation. The aim is to generate or confirm hypotheses about causal relationships while promoting 21st century skills. The framing is chosen in line with specific learning psychology concepts such as problem solving and research skills (Gut-Glanzmann and Mayer, 2018).

Therefore, pupils can actively and independently experiment and apply their knowledge to find a solution to a problem situation, supported by digital media such as augmented reality, virtual experiments, and explanatory videos. This form of competency-based learning allows pupils to deepen their knowledge in a practical way and understand complex relationships. These materials are developed, tested, and evaluated by students as part of their compulsory master's degree program in teaching (Rubner and Lukas, 2023). In addition, pupils are included in development and design work through the establishment of a research AG and thus actively participate in the project (Figure 2).

Figure 2: Integration of project participation among individual groups (own figure)

This enables a focus on their professionalization, in addition to the subject-specific competency acquisition of the pupils, which is an important aspect of the project. The supervision of pupils in the Ex^3-Lab is carried out by chemistry teacher training students who are prepared for supervision in the project as part of their education and receive continuous feedback. Moreover, the scientific supervision and mentoring of students promotes a sustainable exchange between theory and practice, as well as between universities and schools.

The focus of this project is the implementation of an educational escape games with an experimental orientation while it is digitally enriched. Various experiments are implemented in a narrative context. Just like in classical puzzles, combinatorial puzzles, or physical puzzles where for example the artefact has to be changed, the result of the experiment is needed to unlock the next challenge. An example of an experimental sequence is described below.

4.1 Application scenario of a chemical-experimental escape game

The pupils have crash-landed on an unknown planet with their spaceship and are trying to find a way back to Earth. They are standing in front of the command centre, which they need to enter to take control of the spaceship. However, the heavy door to the centre is locked. There is a keypad in front of the door, and as the captain of the ship has become somewhat forgetful in his old age, he had slid an iron plate with the numbers underneath the keypad. However, there are four digits on the plate and only two are needed to open the door. Through exploratory research, the pupils must carry out an experiment to find out how to identify the two correct numbers. Two containers are given, one labelled with a bluish solution (copper ion solution) and the other with a clear solution (distilled water). When the iron plate is dipped into the first and then into the second solution, two of the numbers disappear and the students can use the remaining two numbers as a code to access the command centre. The technical background to this is as follows: It is a cementation reaction that is triggered by immersing the iron plate in a sulphuric acid copper sulphate solution (bluish solution). In this reaction, the more noble copper (as copper ions in solution) precipitates on the less noble iron plate. Two of the digits were stamped on the plate with glycerine, which dissolves when immersed in the solution, as glycerine is water-soluble, so they are no longer visible. The remaining numbers were stamped on the plate with tallow, which is not water-soluble. Since copper cannot deposit on a plate stamped with tallow, the digits become visible (Figure 3). Finally, the students can enter the code (51), the door opens and the game continues.

Figure 3: The electrochemical deposition of copper on iron to visualize the solution numbers 5 and 1

In addition to physical objects, the materials and tools for the experiments and puzzles should be digitally enriched. This is achieved through augmented reality, virtual reality, videos, or apps, that engage learners in a targeted way and support their learning. For example, a fingerprint is made visible in an escape game using the iodine method (Rubner et al., 2018). In this experiment, a trace carrier with a latent fingerprint and some iodine crystals is placed in a vacuum syringe (syringe with a 3-way stopcock and an activated carbon filter, closed system) and by pulling back the plunger, a negative pressure is created in the reaction chamber. The negative pressure causes the crystalline iodine to sublimate, leaving it in a gaseous state. The non-polar iodine molecules are then deposited in the talc-like components of the fingerprint and the fingerprint becomes visible as a brown colour. The sublimation of the initially crystalline iodine is shown in detail in an animation (see Figure 4). As the animation progresses, the gaseous iodine attaches to the non-polar talc-like components of the fingerprint. The AR animation allows students to see the process of sublimation and incorporation of iodine visualised at the particle level (Krause and Eilks, 2020; Schneeweiß and Sieve, 2020; Thyssen, 2017; Wejner and Wilke, 2020).

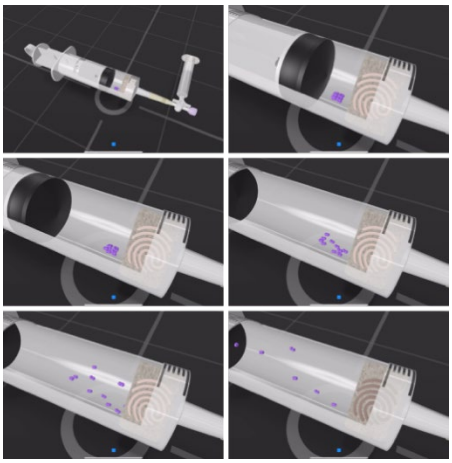

Figure 4: AR animation of sublimation and incorporation of iodine into a latent fingerprint

5. Research Within the Project

The growing importance of escape games in recent years and their potential for educational and innovation research has also been noted (Gentile, Allegra and Söbke, 2019). However, the topic is still poorly researched in the German-speaking region at present. An analysis of previously published articles on the topic of educational escape games (in year 2021), which selected informal and formal educational settings as a framework and were located within the tertiary and secondary education levels, identified 15 publications thus far. Nonetheless, gaps and large differences regarding the focus and research of escape games were found. With the consideration of common classifications of games/rooms, the field is expanding further (Lathwesen and Belova, 2021).

The results of the literature review show that research on escape games is primarily based on experience, observation, and feedback. Only occasionally is there a focus for example on pupils' or learners' interest or motivation. The project Science 4 Exit therefore aims in addition to provide further research and knowledge in this area.

The investigations in the project Science4Exit aim to assess the motivation of pupils and the associated effects on academic learning progress, as well as the cognitive effectiveness of the games. Furthermore, the study aims

to investigate how participating in escape games affects the increase of interest and experimental self-efficacy. Finally, the study also focuses on the digital competencies acquired or reinforced through the games. Specifically, the study uses standardized questionnaires to collect data, which ensure high reliability and validity. Participants will be surveyed before and after each escape game to assess their starting level and changes regarding the variables being examined.

Measured constructs will be learning gain (pure knowledge and transfer to application), intrinsic motivation (e. g., Wilde et al., 2009), flow (e.g., Rheinberg, Vollmeyer & Engeser, 2003), self-efficacy in experimenting (e. g. Atzert et al., 2020; Dahmen et al., 2021) and interest in the subject. Also, the development of 21st century skills will be tackled in the research progress (Care, Griffin, & Wilson, 2018). The pre- and post-surveys enable a targeted evaluation of the learning progress and the effectiveness of the applied teaching and learning methods of the escape games. The collected data will be analysed using descriptive and statistical methods to ensure a detailed investigation of the response distribution. Inferential statistical procedures such as t-tests, analysis of variance, correlation analyses, and multiple linear regressions will also be conducted to explore the relationships between the various variables. The results of the study can contribute to improving the understanding of how escape games can be used to increase interest, motivation, and competencies of pupils in chemistry and other areas. Additionally, the results may also help to develop curricula and learning methods to provide pupils with a broader range of skills.

6. Conclusion and Future Directions

In an educational context, gamification offers the possibility of integrating playful elements into non-playful contexts. The use of gamification in teaching and learning contexts has grown in importance in recent years as it can increase learner motivation and engagement. It is important that games are perceived not only as entertainment but also as a learning environment. To achieve this, the learning content and the game-based narrative context need to be carefully selected and prepared to meet the needs and interests of the learners.

Escape games offer such an opportunity and are defined as interactive games in which players have to escape from a situation by solving puzzles and tasks. In an educational context, escape games can be used to deepen the scientific content learned in school in a playful and interactive way and to establish an application reference.

Today's generation of students increasingly uses digital media in their everyday lives, both for communication and entertainment.

For this reason, the use of experimental escape games with digital enhancements can help to increase motivation and interest in STEM subjects. Through digital enrichment, learning content can be delivered in an interactive and playful way.

The Science4Exit project is developing digitally enriched escape games to improve students' access to science content, particularly chemistry. The aim is to enable students to apply their knowledge and thus increase their interest in science. The digital enrichments make it possible to teach experiments not only in real life, but also digitally. In addition, the escape games use other digital elements such as augmented reality and explanatory videos to give students better access to the subject.

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Exploring Movement-Modifier Facilitation in Movement-Based Sports, Health, and Game Design

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Abstract: It can be daunting to ensure a movement flow that unleashes creativity when facilitating movement-based design activities that aim for play, games, sports, and technology domains. When incorporating movement in game design, it is vital to understand game and learning elements but equally movement and play elements because these are important motivational factors. To fully understand the play, sport, and physical activity aspects of movement-game design, we must investigate the world of physical activity and performance. As a part of the Erasmus+ project, MeCaMInD, the innovative design of Movement-Modifier cards was developed, intended as a tool in the facilitation process to engage participants in physical exploration, supporting, modifying, or tweaking movement-based design practices for an inclusive game and physical activity and performance design. The Movement-Modifiers is grounded in sports and health theories, creative design tools and methods. To harvest the Movement-Modifier's tweaking creative potential, it is crucial to understand when and how to use them in the generative parts of a movement-based design process. Grounded in a phenomenological approach and based on a multiple case study, this paper explores how eight facilitators used the Movement-Modifiers to challenge and tweak the generative processes. The cases are 1) A two-day sports innovation camp for 80 K12 high school students, 2) A workshop on Inclusive exergame design with 15 participants at the Nordic Innovation Summit 2022, 3) A course teaching 65 sport bachelor students the creative acrobatic body performance design. Empirical data were generated using a combination of observations, video recordings, and interviews, and the phenomenological analysis was condensed into written facilitator narratives. We present Movement-Modifier facilitation strategies in three phases of movement-based design facilitation, illustrated on a continuum with the facilitator's level of involvement on one axis and participation structure on the other. The facilitator's role is multifaceted, and effective Movement-Modifier facilitation requires sensitivity, adaptability, and careful planning. The Movement-Modifiers should be seen as a tool to support the design process rather than the essence of it.

Keywords: Movement-based Design, Embodiment, Movement-modifiers, Facilitation, Exergame, Game-based

1. Introduction

The game-based learning community is increasingly attentive towards movement-focused and playful applications, such as exergames, VR exertion, rehabilitation, dance, and circus (Segura, E. 2019), and learning games combined with physical activity (Reidsma et al, 2022). Thus, we see movement as a vital element in games and play (Erkut and Dahl, 2018) and recommend that designers use movement as part of the design activity to build awareness of the fleeting and immediate movement experiences (Schleicher et al, 2010; Segura E. 2018). Physical movement as a source of creativity has been explored by Márquez-Segura, (2018), Schleicher (2010), and Vidal (2018), who points to design technics and the challenges of enabling the right state of a body-being for participants. Exploring physical movement as a medium of creativity often requires a designer to facilitate the right mindset by choosing and interconnecting methods to form an appropriate process and modify it accordingly. Svanæs & Barkhuus (2020) argue that the designers' active involvement is crucial for using Movement-based Design Methods (MbDM). Thus, we wish to understand how the designer must possess both sensitivity and skills to facilitate the process of MBD.

In the MeCaMInD (Method Cards for Movement-based Interaction Design, 2023) Erasmus+ project, we strive to make the increasing number of MbDM accessible to engineers, designers, and students by making physical design cards. Concretely, we have gathered MbDM into an easy-to-use method card toolbox. Our mission is to assist in creating more sustainable movement-game solutions and engaging MBD activities. In the project, we uncovered theories supporting MBD, made inventories of existing methods, categorised them, and made a model (the 4M framework) of four distinct card categories (Elbæk et al, 2022).

The model is founded on the theory of embodied cognition that builds on radical embodied cognition summarised in the 5E's, embedded, embodied, enactive, extended, and emotive to approach and understand the concept of embodied cognition (Malinin, 2019; Stilwell & Harman, 2022). The embodied premise situates the body as an intrinsic part of a larger cognitive system, which spans the mind, body, and environment. The embedded thesis suggests that affordances shape the unique bodily capacities we shape as we interact with our

social and physical context. The enactive element points to our sensemaking and embodied experiences are created through interactions with the environment in an interwoven process between action and perception. The extended element claims that our mind's boundaries are open, flexible, and distributed beyond our body. Design methods linked to the 4M model, we recommend using an open and situational creativity-in-the-wild approach (Malinin, 2019). The 4M model illustrates a box placed on top of Movement-Modifiers, which we will use along with the three other types of method cards (Mood Setters, Movement Methods, and Movement Concepts).

This paper addresses one specific design hurdle in MBD. In our experience, movement-centric design activities are often interrupted by cognitive activities of talking and writing. We have seen specific strains on the facilitator who mediates MBD activities, ensuring a movement flow that unleashes creativity. We used props as modifiers and developed movement-focused Modifier cards consisting of words or images to provoke divergent thinking. However, we have experienced that it is challenging to facilitate and use the Movement-Modifiers: how and when to use and choose between the 300 cards combined with the physical props.

This paper explores the facilitation and use of Movement-Modifiers during MBD activities. To fully understand the play, sport, and physical activity aspects of movement-game design, we include cases in which the design for physical activity and the design of physical performance are embraced, as these movement and play elements are important motivational factors in movement-based games such as exergames, exertion games and movement-based learning games. Our goal is to make the MBD more accessible since the learning-game industry needs designers to facilitate the methods and educators that can teach students the use of MBD.

We will investigate the Movement-Modifier use and facilitation in three design workshop cases. We describe the cases, provide condensed phenomenological facilitator narratives, and embed our discussions in literature, interview and observation context, and experiences facilitating MBD activities. Finally, we provide guidelines for using Movement-Modifiers in the design of movement and learning games and in the design of movement activities and teaching these activities.

2. Movement Modifier Design Card

The development of the Movement-Modifier cards is grounded in sports and health theory and further informed by analogue tools that provoke divergent thinking and core design knowledge like https://innovation.sites.ku.dk/metode/inspirationskort/, (2023). Movement-Modifiers contain one or a few words or images that aim to provoke, tweak, or inspire generative design activities. The cards relate to knowledge, theory, and practical movement concepts in the domain of sport, technology, games, plays, and movement practices.

Figure 1: Examples of the MeCaMInD Movement-Modifiers

The Movement-Modifiers are categorised into modifying Movement, Structures, People, Motives, and Artefacts and hold 17 different types of cards plus a card type to make your own modifiers. The category of Modifying Movement holds cards with basic movement, movement perspectives, and training elements. The category Modifying Structure grasps play & sports disciplines, play elements, and play perspectives. Modifying Motives holds metaphors, logic, stances, & values, and Role & Perspective. Modifying People contains persona, environment, impairment, and constraint. Modifying artefacts includes technologies, game genres, game structure, and game perspectives. Supplementary to Movement-Modifiers are Instruction Cards suggesting the use of various music and physical artefacts such as props and DIY material.

2.1 Informed Design of Movement Modifiers

Freach (2010) positions design tools to frame or reframe design challenges, facilitate dialogue externalisation of insights, use existing knowledge in the first place out of sight, visualise problems and solutions, and equip teams to learn about users. According to Sanders and Stappers (2014), physical artefacts allow groups to think through design and play with materials striving for the new not yet known. Based on Peters et al. (2021), we categorise the Movement-Modifiers as Prompts that include tools encompassing provocative questions, triggers, or abstract terms or visuals to prompt divergent thinking. The Movement-Modifiers allow participants to externalise and reorganise systems during the design work. A benefit of using analogue cards is that they are a tangible and interactive artefacts (Daly et al., 2012).

When designing design cards, it is important to understand how these cards can contribute to the design process. In this article, we mainly focus on the divergent or creative parts of the design process, and the Movement-Modifiers aim to support these activities. Along with Biskjaer, Dalsgaard and Halskov (2017), we see divergence as a process of expanding the design possibilities by identifying new options beyond the immediate design space. Divergent thinking is important in a creative process because it allows the discovery of many possible ideas and combinations that may serve as solutions.

Various movement practices, such as dance, performance art, yoga, and martial arts, utilise the body as a creative tool for expression and exploration. Dancers use the principle of improvisation to generate new movement possibilities, while performers may draw on characters or themes to create their own movement performances. An approach we used in designing the Movement Perspective cards was by using Rudolf Laban's BESS Framework. Dancers use the framework to experiment with various body shapes, applying different levels of effort, such as light or heavy, and the space in which the movement occurs. These content elements are included in the cards. In yoga and martial art, movements are a tool for self-expression and exploration, and the focus is also on your body's inner presence and feel. Inspired by these divergent movement practices, we designed the Movement-Modifiers.

2.2 Facilitating Movement-Based Design Practices

Facilitation is the process of applying design processes and approaches to enable exploration, ideas and decisions to emerge when developing solutions, which requires design process knowledge and understanding (Mosely et al. 2021) The role of the facilitator significantly impacts participatory activities and outcomes, as Dahl and Sharma (2022) state. Based on the facilitator's strategies and responsibilities, they propose six facets of the facilitator role: Trust builder, enabler, inquirer, direction setter, value provider, and user’s advocate. Starostka et al. (2021) state that facilitation is done in multiple ways and describes four facets of facilitation: tool vs mindset perspective, problem vs solution focus, planned vs emergent process, and individual vs shared leadership.

Little focus has been on facilitating movement-based activities. Thus, Reidsma et al. (2022) propose that the facilitator in movement-based design can draw upon various role-related perspectives and activities, including the Instructor and Game Master, Coach and Mediator, Role model, and Initiator and Animator. The Initiator and Animator roles are essential in controlling the purpose of the activity, focusing on the energy in the process, and exploring emergent movements. These roles create prerequisites for new paths of movement, encourage movement inquiry, an open space for wonder, support exploration, and let the art of improvisation be a driving force (Borghäll, 2019). We propose using cards such as Movement-Modifiers to support the various facilitator activities and roles, plus using a palate of strategies to facilitate movement-based design activities. This allows us to question how we can stimulate people with prompt cards to be in divergent design stages using their bodies as modus for identifying new ideas.

3. Cases and Methods

To ground this study in the carnal realities of the lived body, we adopted an existential-phenomenological frame along with the phenomenological attitude (Allen-Collinson, 2009) and chose an explorative approach. We used a multiple-case study design to develop an in-depth, comprehensive, and context-dependent understanding of Movement-Modifier facilitation (Stake, 1995). The cases included were 1) Bright over Night Movement 2022, 2) Exergames for Equality, and 3) The Creative Acrobatic Body. These will be introduced below.

3.1 Bright ver Night Movement 2022

Bright over Night Movement (BoNM) is an innovation camp based on a collaboration between a Danish high school, the municipality of the high school, and the regional university. The high school aims to incorporate

innovative design thinking in Physical Education (PE). Participating in a two-day movement-based sports innovation camp, the PE students generate sports and health solutions based on relevant and authentic cases offered by the municipality. The 2022 camp was held 8-9th December. The cases are presented in Table 1. The Liedtka design model (Liedtka & Ogilvie, 2011) provided the framework for the design process. The first day of the camp focused on the *What If* and *What Wows* stages, and the second day was on *What Works*.

Table 1: Outline of the Bright over Night Movement 2022 (BoNM22) high school innovation camp

Workshop BoNM22	
Theme	Innovation and design thinking in PE
Aim	To create a 20 min activity for either: ▪ Children in a kindergarten ▪ Eighth graders in middle school ▪ Seniors in an activity centre
Participants	80 K12 high school students 4 facilitators are master students from the local university 6 facilitators are PE high school teachers
Context	Classrooms and gyms at a Danish high school. (15 hours in total)
Outcome:	Participants created a 20 min activity for one of the three cases, tested it on their respective target group and presented their solutions to local health experts, politicians, and municipality professionals

3.2 Exergames for Equality

At the Nordic Sports Innovation Summit (NSIS) held in Odense on the 29th of November 2022, a movement-based design workshop on Inclusive exergame design showcased The MeCaMInD Project Toolbox. The aim was to create exergames where people with and without disabilities could play equally. The workshop consisted of three parts, starting with framing the design challenge. Next, a physical part, starting with a warm-up activity followed by explorative group work to create playful games compatible with the lymb.io MultiBall Wall and ending with presentations of the games and sharing knowledge and feedback. The participants worked together to create inclusive games.

Table 2: Outline of the Exergame on equal terms workshop at the 2022 Nordic Sports Innovation Summit

Workshop NSIS	
Theme	Inclusive exergame design
Aim	Create a game compatible with the MultiBall Wall for people with and without disabilities and test the Card toolbox from MeCaMInD project
Participants	15, including students, researchers, NGO and organization representatives, and teachers from Denmark
Context	Lab for Play and Innovation at the local University, 1.5-hour workshop
Outcome:	Participants created 4 inclusive games compatible with MultiBall Wall system and tested the Movement Modifiers

3.3 The Creative Acrobatic Body

The Creative Acrobatic Body is a 4 ECTS bachelor course for Sport Science Students at the local university. The students' task was to create a bodily acrobatic performance informed by or invented from movement cultures of their choice, e.g., parkour, new circus, cheerleading, creative gymnastics etc. The students' assignment was to produce an informative, inspirational video showing parts of the performance and core elements of the process of creating said performance or facilitating acrobatic creativity. The course is structured as 1) formalised lectures and 2) practical workshops. Central was the first workshop introducing the MeCaMInD card box and the 4M model, mood setting, generation, testing, and documentation of acrobatic performance.

Table 3: Outline of the Creative Acrobatic Body Course using MeCaMInD Movement Design Methods

Creative Acrobatic Body Course	
Theme	Design of acrobatic movement
Aim	Create a creative acrobatic performance and facilitate a workshop in creative acrobat practice for a defined high school student group
Participants	65 second-year PE and sports science students, joining the Sports and Health educational programme at the local university
Context	The local University gymnastics centre, 3-hour embodied creativity workshop + 30 hours of teaching of various acrobatic cultures and self-guided facilitation creating acrobatic performance and teaching practice for school students
Outcome:	17 performance and facilitation instruction videos

3.4 Data Generation and Analysis

Observations, video recordings and interviews with the facilitators generated rich, in-depth facilitator narratives of the lived experiences of the Movement-Modifier facilitation.

Written consent to do the observations and video recordings and to use the information in this study was collected from all participants and facilitators within this study.

Informed by phenomenology (Ravn, 2016), specific observation points related to the facilitation using Movement-Modifiers (Context, Social Dynamics, Moderation, Enabling) were included in an observation guide along with phenomenological focus points (the *what*, the *how*, sensorial impressions, curiosity, epoché, and openness).

Videos were recorded at BoNM22, at the Exergames for Equality workshop, and produced by students at the creative acrobatic body course to generate observation notes.

An interview guide was developed based on a rapid review of design facilitation, observations, and video recordings. Eight semi-structured interviews lasting 45-60 min were conducted and carried out individually with each facilitator from one of the three cases. The facilitator was asked to focus his/her descriptions on their own experiences and answer the questions with as many concrete examples as possible, striving for phenomenological reduction (Høffding and Martiny, 2016).

The interviews were recorded and transcribed verbatim. Along with the observations and video recording notes, the empirical data were coded according to the terms 'emic' and 'etic' in a heuristic and iterative process as described by Ravn (2021). When conducting the emic coding, we performed a 'line-by-line' reading (van Manen, 1990). Subsequently, we organised the notes into themes that concerned different aspects of the facilitators' experiences with Movement-Modifier facilitation. Following, we emphasise condensing text into written narratives informed by Creative Analytical Practice (McMahon, 2016). We apply an autoethnographic style that allows us to write in first-person format (McMahon, J., 2016), grasping the lived experience of facilitating using Movement-Modifiers. We strive to express what and how, including the sensing, acting, experiences, and reflections of being an involved facilitator.

4. Findings

4.1 Sensitivity and Controlled Card Facilitation

During BoNM22 I observed that being a facilitator using the Movement-Modifiers requires sensitivity, constantly analysing the situation, sensing the participants' needs at any given moment, and acting accordingly, which makes the role of the facilitator quite intense. For example, Catherine told me: "You can observe, listen, and sense the group, look at the Movement-Modifiers in your hands and play the card(s) you think will help the group, whether to tweak the ideas or add energy to the process." Some groups struggled to start or maintain movement flow and bodily creativity. In these moments, the facilitator stepped in and played a Movement-Modifier for the group. To me, that is a controlled Movement-Modifier card facilitation style.

Anna and Catherine told me: "Before BoNM22 we picked out 30-40 cards from the deck. Despite thorough preparation, we still found using the cards as novice Movement-Modifier facilitators challenging. Often, we experienced becoming passive card-flipping facilitators. However, we learned through the process and feel confident that our knowledge of the Movement-Modifiers will make them more manageable to structure and use next time.

Ida and Eva mentioned, "One group went through many Movement-Modifiers quickly and performed one movement on each card. Another group got the Movement-Modifier 'balance' and decided to lift one leg while continuing to throw a ball to each other. We realised that as a facilitator, you must also be aware of *how* the Movement-Modifiers are used".

Emma and Alfred said "balance" on the Movement-Modifier out loud to all the participants. "This was an in-the-moment decision because we did not plan how to structure the use of the Movement-Modifiers in advance. Doing this, we experienced a group exploring dynamic movement patterns when the Movement-Modifier was announced. This destroyed the movement flow of the group, making them passive, not knowing how to continue." It seemed they got the wrong Movement-Modifier at the wrong time, so timing the use of the Movement-Modifier is essential.

4.2 Modifying the Explorative Phases With Impaired and Non-Impaired Designing Together

In the long middle part of the workshop, the teams tried out things with tools on the wall. During this exploratory phase, the teams used the Movement-Modifiers to explore and experiment with their ideas, thus adding valuable insights. I enjoyed observing the groups getting new crazy associations that helped create their games.

I pre-selected Movement-Modifiers, 40 cards per group, and let the groups decide their Movement-Modifier use and how much or little they should influence their process. I arranged the cards by category and would, e.g., tell a group, "You could consider using these cards" or "This card might be useful because it deals with this," without forcing them.

Due to the schedule with tight deadlines, we needed to allow ourselves to make creative detours. For the Movement-Modifiers to make a meaningful impact, it is necessary to allocate sufficient process time. Also, the wheelchair users and the technology devices made the external factor of physical space a limitation to moving and exploring game options. Especially the use of balls, cones, etc., was restricted by the limited space.

I experienced when having impaired and non-impaired people working together, creating a safe atmosphere was crucial when using the Movement-Modifiers. I had to make sure that the participants were comfortable and trusted me to guide them through the process of reaching the end goal. I could steer the process by sensing the groups' moods and having a feel for them. I observed body language and listened to their talk. It was a mix of being present with all my senses and following my plan. Also, I let the participants know that the cards would add more value if everyone allowed themselves to be in the moment using Movement-Modifier.

4.3 Facilitating for “Design of Movement” in Creative Acrobatics

During my intro workshop, I noticed a group repeating the same movement patterns and wondered if they were limiting themselves or just playing out sports habits. I returned to the Movement-Modifiers to select cards to inform new movements. The Movement Elements and Play Elements cards were particularly helpful, as they tweaked the habit of movement patterns and endorsed creativity.

A group chose the "Floating Like Lava" card and used it to move forward with their new circus narrative theme. I realised that if I had presented all 19 cards with Metaphors, they would have been confused and unable to make fast decisions and start or keep up the creative flow.

When I choose Movement-Modifier cards, I typically sort them and discard any useless ones before selecting the most appropriate ones. When approaching a group, I intuitively determine which of the chosen Movement-Modifiers to offer.

As a facilitator, I offered options but never forced card use due to supporting empowerment and promoting ownership. I tried to keep the energy flowing in the process, and contrary also made room for creative frustration and development. Finally, I was impressed by how the students used Movement-Modifiers to facilitate their process for fellow students. They became more conscious of the processes and could anticipate their direction. Facilitating with Movement-Modifiers requires being in the spider's web centre, sensing the tension in all threads. Overall, it was a fulfilling experience to see the students develop their skills and creativity with Movement-Modifiers.

By adopting a phenomenological approach, we generated valuable data. We wrote condensed, in-depth narratives that captured the real-life experiences of utilising the Movement-Modifiers of the MeCaMInD method card box during Movement-Modifier facilitation. Our analysis has yielded several insights, which we will outline in the following analytical model. Additionally, we will discuss specific topics and provide recommendations based on our findings.

5. Discussing Insights From Facilitating Movement Modifier use

In Figure 1, we extract the essential Movement-Modifier facilitation strategies from the three cases’ narratives and position the strategies. We visually depict these in three phases of facilitating a design process: 1) When planning a workshop using Movement-Modifiers, 2) In-the-moment Movement-Modifier facilitation strategies, and 3) Effect of using the Movement-Modifiers.

On the vertical axis, the facilitator’s level of involvement entails. Being the Observer, the facilitator keeps a distance from the participants and ultimately lets them do the playing. As the Animator, the facilitator briefly joins the design activity in a more immersed and involving manner, exploring one’s and the group’s experiences and energising the process.

The horizontal axis represents how the facilitator structures the participants' empowerment option, which is analysed on the range between control and shared participation. Controlled Participation implies how the facilitator steers the process and the use of Movement-Modifiers, deciding which Movement-Modifiers to use and when to play them. Facilitating controlled participation will provide options for ensuring a safe atmosphere. However, the facilitator can let the participants decide on their Movement-Modifier use and provide only light guidance and freedom to utilise Movement-Modifiers as preferred, characterised as Shared Participation.

It is important to note that we observed and experienced a continuum of the axis, and the facilitator's involvement level and participation structure can change during the design process.

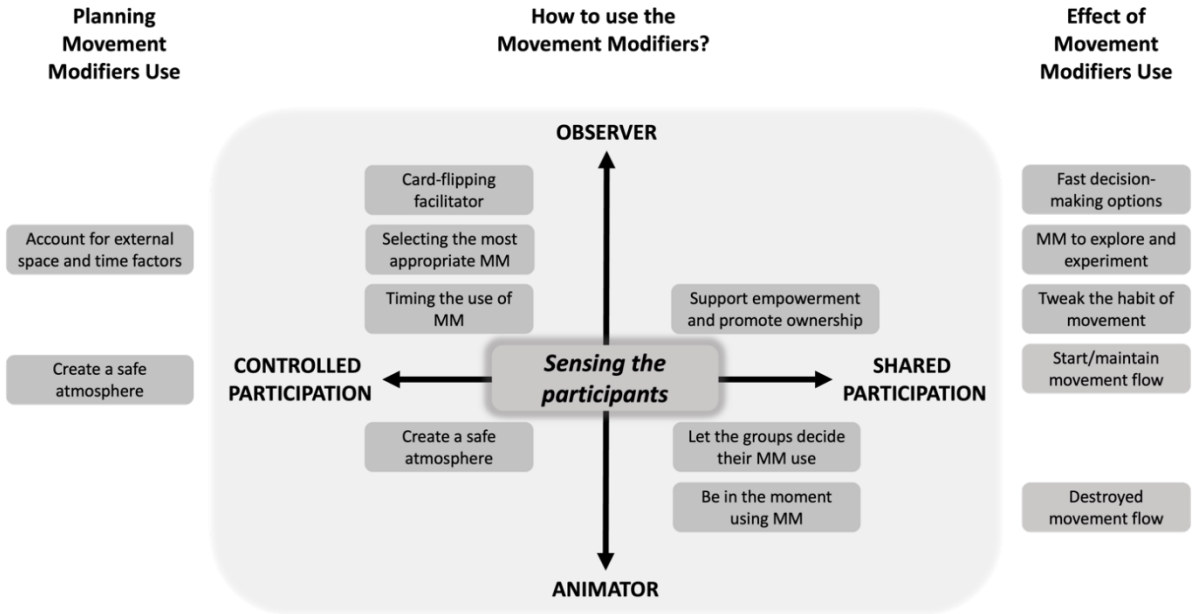

Figure 2: Planning, Facilitation, and Effect Model using MeCaMInD Movement-Modifiers

Through the narratives, we identified that physical and mental elements like space, time, and mindset could limit Movement-Modifier's possible value and the opportunity to make creative detours using Movement-Modifiers. The facilitator must be aware of this when planning a workshop for movement-based game design. As Van Loon & Larsen (2017) argue, facilitation is relevant before, during and after. As in every design activity, practical issues tend to take up too much focus. A facilitator must prepare the physical space, relevant resources, and music, engage participants, etc. A thorough planning is essential to establish a solid foundation for the best possible outcome using Movement-Modifiers. In movement-based game design activities, the physical space and design resources are highly important for the process as the participants need this to explore and move around. To create optimal conditions for each activity, we recommend being a Game Master (Reidsma et al, 2022), focusing on setting up the activities in advance.

As emphasised in the three narratives, facilitating a design thinking workshop using Movement-Modifiers and other materials requires a sensitive and adaptable approach. Thus, facilitators must be aware of what is happening, sensitive to the use and effects of Movement-Modifiers, and aware of the participants' needs to support design progress during facilitation.

Regarding getting most movement creative insights, the facilitator must be careful not to disrupt the movement flow by misusing method cards or focusing too much on their use. Instead, Movement-Modifiers must be seen as a tool to support the design process rather than the essence of it.

6. Recommendations Using Movement-Modifiers

To be an effective facilitator, it is essential to establish knowledge about the group and prepare design materials, including physical props and method cards, and possibly use a gameboard for card preparation. Clear communication with participants is vital, and facilitators must practice their instruction to use the chosen method cards. The facilitator must also practice the roles sketched by Reidsma et al (2022): the game master when planning workshops, and the instructor initiating mood-setting activities, creating a creative body being and guiding using Movement Method and Movement Concepts combined with the Movement-Modifiers. The coach asks guiding questions creating optimal design insights, the role model shows how to be a full-blown

designer, the initiator/mediator to initiate necessary actions, and the moderator when necessary, intervening in the design process to ensure it provides optimal energy, flow, and creation of design insights.

In most cases, controlled facilitation promotes a safe atmosphere, although shared facilitation done carefully can also support a safe atmosphere and encourage shared participation. However, it is essential to strike a balance between too many Movement-Modifiers disrupting the flow and the benefits of empowerment and ownership on the participant side.

In summary, facilitating a design workshop using Movement-Modifiers requires sensitivity, adaptability, and careful planning. Movement-Modifier cards should be seen as a tool to support the design process rather than the essence of it. Effective facilitation involves establishing knowledge about the group, preparing design materials, and clear communication with participants. We encourage the facilitator to practice their roles as coach, moderator, initiator, mediator, role model, and animator and intervene embodied when necessary to ensure the design process stays on track. Finally, shared facilitation can be helpful when the users' voice is essential for ownership of the design outcome. Still, balancing disrupting the flow and promoting empowerment, democratic involvement, and ownership is critical. Thus, as an exergame and exertion game designer and movement learning game designer, you will gain from practising and using your movement skills when facilitating movement-based design workshops.

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Using and Facilitating Social Videogames as Warm-Ups for Embodied Design

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Abstract: Warm-ups, as preliminary activities to physical training, are an inherent part of any physical exercise and sports practice. Rooted in the concept of embodied cognition, embodied design is a paradigm that shifts the focus of interaction design from external artefacts and devices to the human body (Svanæs & Barkhuus, 2020). A body-centred design emphasises the importance of having the human body at the centre of the entire design cycle, conveying movement, physical expressivity, feelings, and aesthetics, in a design process that uses the body as both a resource and target. Designing with the body is, therefore, a physically demanding activity that requires a specific set of warm-ups to educate and prepare designers mentally, socially, and physically for the act of embodied design. We propose social videogames as a resourceful framework for creating such a set of warm-up exercises. This paper presents a methodology comprising off-the-shelf commercial videogames whose rules have been adapted for embodied design. Three studies have been executed to validate the game's capacity as warm-up activity and icebreaker for embodied creativity and to study the conditions for an optimal method facilitation to external instructors in preparation for an applied session. The method applied is qualitative and quantitative feedback data gathered from the three studies using questionnaires, tests, observation, and open interviews. The results of the series of studies showed the potential of the proposed methodology as warm-ups for teaching, training, and practising embodied design, as well as giving insights on how to facilitate it. Overall, the game-based warm-ups for embodied design preparation using off-the-shelf movement games have a social and playful nature. The proposed twisted gameplays make them suitable to exert body moves and get ready to think and design with their bodies. The study on facilitation shows the need for a preparation session supported by an experienced person. However, one introductory session is enough for the toolbox to become an easily configurable resource that adapts to the facilitator's needs and goals. We suggest including sample implementation cases along with instruction cards of the embodied games. Further, the warm-up games are customisable using the toolbox's modifier cards.

Keywords: Warm-Ups, Embodied design, Social games

1. Introduction

There is a strong connection between social videogames and embodied interaction. Social play requires several players to engage with a game simultaneously, relating to higher inter-player competence and reduced tension and frustration. Existing social games include many examples of alternative controllers that frequently invest in technology-enhanced embodied interaction. Academia has proposed many frameworks from the field of HCI for body-centred interaction design (Turmo Vidal, et al., 2021), as well as the game industry has released many games and platforms that make use of alternative controllers that enable body interaction, such as Nintendo Wii and Switch, Just Dance, PlayStation Move, Microsoft Kinect, etc. Research points out potential unexplored benefits of the body's involvement in play (Canossa, et al., 2020).

We propose that a selection of commercially available social games can be used as a framework for designing and implementing a set of warm-ups for embodied design, described, set-up, and performed to bring embodied design closer to a broader target audience. We proposed modified how-to-play instructions for these games, designed to increase the embodied creativity aspects of the gameplay. This method has been tested in subsequent studies to validate its capacity as warm-up activity and icebreaker for embodied creativity, as well as to study the conditions for an optimal method facilitation (Reidsma, et al., 2022) to external instructors in preparation for an applied session. The paper discusses the results obtained through qualitative and quantitative feedback gathered from all the presented studies using questionnaires, tests, observation, and open interviews.

This research takes place within the scope of the Erasmus+ project MeCaMInD: Method Cards for Movement-based Interaction Design. Therefore, the proposed method's application domain is embodied design, which aligns with the project's core goal of enhancing a movement-based creative design environment that paves the way towards designing more sustainable movement technologies for people’s everyday life.

2. Related Work

Play appropriates the environment where it takes place (Sicart, 2014), relating our bodies to things, places, ideas, and feelings (Ryding & Fritsch, 2020). Existing research points out several benefits associated with games, from surgical preoperative warm-ups (Jalink, et al., 2015) to social icebreaking activities (Depping, et al., 2016), including knowledge acquisition, as well as affective, behaviour change, perceptual and cognitive and physiological outcomes (Boyle, et al., 2016). Social interactions that occur through play lead to genuine bonds, particularly optimal for trust formation. Interpersonal trust is a relevant factor in team performance and efficiency. Groups accept playing ice-breaking games as a viable team-building exercise, with positive effects on group communication in terms of talking activity and group member participation (Depping, et al., 2016), as well as potential benefits in subsequent face-to-face collaborations (Nasir, et al., 2013).

Embodied gameplay can unlock creativity through movement-based exercises and embodiment practices (Ludevig, 2015; Altarriba Bertran, et al., 2020). When comparing the effects of playing the same games with or without different sorts of embodied interfaces (Canossa, et al., 2020; Frommel, et al., 2017; Robinson, et al., 2020), results show that embodied versions enhance social interaction, enjoyment, affection, and an overall better experience. Body-based controllers in games show a strong effect on the participants' experiences, emphasising the aesthetic and further supporting people to feel closer and more connected (Canossa, et al., 2020; Robinson, et al., 2020).

2.1 MeCaMInD

The MeCaMInD (Method Cards for Movement-based Interaction Design) Erasmus+ project strives to make movement-based design methods (MbDM) accessible to a broader audience. We see movement as a vital element in games and play (Erkut & Dahl, 2018) and a key design activity to build awareness of the fleeting and immediate movement experiences (Schleicher, et al., 2017; Marquez-Segura, et al., 2018; Friis & Elbaek, 2017).

Embodied movement is a source of creativity to design technics and the challenges of enabling the right state of body-being (Marquez-Segura, et al., 2018; Schleicher, et al., 2017; Turmo Vidal, et al., 2018). Its exploration requires a designer to facilitate the right mindset and state of a body being by choosing and interconnecting mood setting methods to form an appropriate process and modify it accordingly.

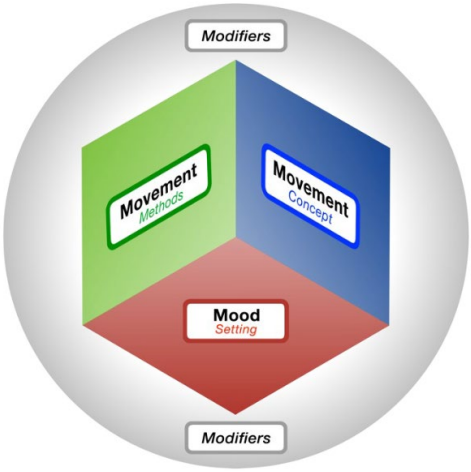

Figure 1: The 4M model with the mood setting activities as the foundational part, extracted from (Elbaek, et al., 2022)

MeCaMInD has gathered MbDM into an easy-to-use method card toolbox by making inventories of existing theories and methods, categorised them, and made a model (4M) of four distinct card categories to make the method cards actionable in the field of interaction design (Elbaek, et al., 2022). The 4M model is founded in the theory of embodied cognition 4E, extended, embedded, enactive, embodied and supplemented with the fifth E as emotive (Stilwell & Harman, 2021). The 4M model (Figure 1) illustrates a box placed on top of movement modifiers, which are to be used along with the three other types of movement method cards or as stand-alone cards. This paper introduces and describes the game-based warm-up exercises as part of the mood-setting methods.

3. Proposed Method

This section describes the set of designed warm-ups, implemented using commercial videogames whose how-to-play instructions have been adapted to better fit embodied design purposes. Figure 2 shows the front side of the mood-setting cards in MeCaMInD's toolbox that convey each of them.

3.1 Just Dance 2021 for PlayStation 4

Just Dance (Ubisoft, 2022) is a popular multiplatform multiplayer rhythm game series since 2009, where players dance pre-recorded choreographies for a given set of songs by mirroring the moves performed by avatars on the screen, getting rewarded by their timing and accuracy. This project uses the PlayStation 4 version with the PS Move motion sensor controller, up to four players simultaneously.

Players are tasked to play trios and quartets: songs with more than one avatar on screen that challenge each player with different moves and offer punctual physical player interaction in their choreographies. This is as a warm-up activity for players to perform a physical warm-up by mimicking choreographies and relating body movement to physical expressivity. Moreover, since it is a group activity, this also works as a social icebreaker to foster competition by performing accurate and well-timed body movements.

3.2 BUTTON for PC

BUTTON (Copenhagen Game Collective, 2011) is a local multiplayer PC game where up to 8 players compete in a series of physical minigames with changing rules pseudo-randomly picked by the computer. All minigames ask players to take some steps back from the screen to then approach the screen by (or after) following a specific rule to achieve a given goal. Both rules and goals are deliberately ambiguous to a certain extent. I.e., players take 7 steps back, then approach the screen in slow motion, and the winner is the first player to press the A button exactly 3 times on her controller. The computer can't supervise whether players follow the indications, so they are collectively responsible for interpreting and playing by the rules. Winners are awarded medals that accumulate during the session. Completing a minigame takes around 20 seconds.

The adapted gameplay replaces each minigame's rule with quick charades challenge they need to pass as a group before they can continue completing the minigame's goal. Players turn away from the screen. Three of the players pick one card (from a pre-set deck) with a word to be guessed by the fourth player using their body expressions so that no speaking is allowed. Upon a successful guess, all four players turn back to the screen to read the minigame's goal and complete it. Another player takes the role of the guesser before the next minigame starts. Ten minigames are played in a row using this modified gameplay.

Charades adds body movement, creativity, and observation, while still participating in BUTTON's competitive gameplay. It also inserts cooperative gameplay inside the competitive nature of BUTTON, which enriches the social interactions during the gameplay.

3.3 Copy-Dance in 1-2 Switch for Nintendo Switch

Copy-Dance is one in the 28 minigames contained in 1-2 Switch (Nintendo, 2017), a multiplayer party game for Nintendo Switch, where two players face each other while holding the console's Joy-Cons. Copy-Dance asks one player to perform a body pose, then tasks the second player to mirror it as accurately as possible. Scores are calculated according to how well players mimicked the opponent's poses by comparing movement, force, and timing.

For the modified version, a third player constrains body moves by proposing topics for each round (i.e., animals or feelings). This encourages players to be body creative by quickly designing and performing a set of body-moves that express specific concepts.

3.4 Johann Sebastian Joust in Sportsfriends for PlayStation 4:

Sportsfriends (Die Gute Fabrik, 2014) is a compendium of local multiplayer party games available for PC, PlayStation 3 and 4. Among them, Johann Sebastian Joust is a music game with almost no graphics designed for PS Move motion controllers. Players hold a motion controller that is very sensitive to movement. Their goal is to be the last player standing while J.S. Bach's Brandenburg Concertos are being played. When a player's controller is shaken beyond a threshold, the player is out of the game. This can happen either due to a player accidentally shaking her controller too much while moving or after being jostled by another player. When the pace of the background music raises, players are allowed to move quicker temporarily.

The twisted version replaces the goal by tasking players to create a group choreography inspired by the music, traversing their interpersonal space and encouraging them to be body creative while avoiding getting eliminated from the game. Players participate in a sandbox experience for body expression. They experience free movement, both personally and as a team, while interconnected and employing shared gameplay.

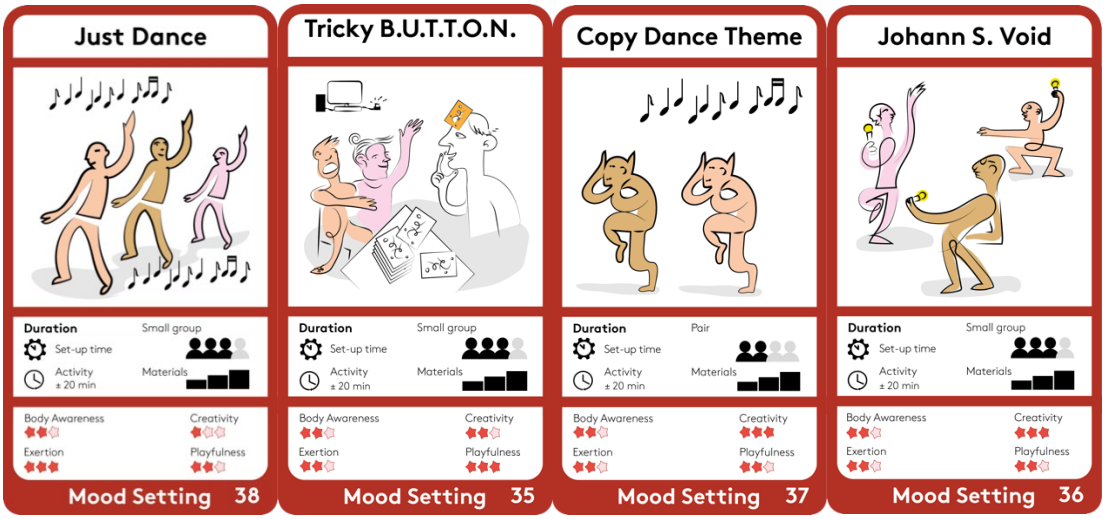

Figure 2. Mood setting cards (front)

4. Study 1: Social Games as Warm-Ups for Embodied Design

Study 1 takes place over a three-hour session. Participants first complete a pre-test composed by short exercises to assess their domain-specific creativity, creative self-efficacy, belief in creativity training, and domain-general creativity (Hänninen, et al., 2020). Participants experiment every game-based warm-up and fill out a post-test questionary.

A chairperson introduces participants to the games and solves gameplay-related or technical questions. Two observers take notes of the participants' performance. Verbal informed consent is obtained from the participants, and it is made clear to them that they can withdraw from the study at any moment.

Table 1: Questions were included in the individual pre-and post-tests. except for the Likert-Scale questions, the left and right columns show the pre-and post-test questions, respectively

Domain-specific creativity	
Pre-test	Post-test
Surströmming ("sour herring") is a lightly-salted fermented Baltic Sea herring traditional to Swedish cuisine since at least the 16th century. The fermentation process takes at least six months, and it is well known as one of the most putrid food smells in the world. Give as many creative ideas to motivate people to consume it. You have 10 minutes to do this.	Saltlakrits (salty liquorice) is a variety of liquorice flavoured with ammonium chloride, and it is very popular in Sweden as well as in the Nordic countries. It gives salty liquorice an astringent, salty taste, which adds bitterness to the flavour and leaves a dry and sharp taste on the tongue. Give as many creative ideas to motivate people to consume it. You have 10 minutes to do this.
Domain-general creativity	
Pre-test	Post-test
What is blue? Try to list as many different ideas in 2 minutes.	What is red? Try to list as many different ideas in 2 minutes.
Creative Self-efficacy and Belief in Creativity Training. Likert-scale questions from "Strongly disagree" to "Strongly agree", included in both pre- and post- tests.	
I feel that I am good at generating novel ideas.	
I have confidence in my ability to solve problems creatively.	
I believe that I can help others to further develop their ideas.	

I believe my creativity will advance by deliberately practicing and exercising my creativity.
I believe my creativity will advance through playing games that make me move and interact with others.

Pre- and post-tests are composed by the questions in Table 1, answered individually and anonymously, inspired by the experiments in creativity testing by Hänninen et al. (2020). Participants are then asked to participate in a group exercise described in Table 2. Two judges evaluate all answers independently, scoring them from 1 to 5 in four categories: originality, fluency, flexibility, and elaboration. This allows us to evaluate features in the proposed answers and the participants' performance while representing them.

Table 2: Exercises included in the group pre- and post-tests

Domain-general creativity	
Pre-test	Post-test
Participants are given several coloured hoola hoop rings. They're given 10 minutes to propose and discuss in groups as many non-conventional uses for them as they can imagine. After this time, participants are asked to perform all of them.	Participants are given several coloured dance scarves. They're given 10 minutes to propose and discuss in groups as many non-conventional uses for them as they can imagine. After this time, participants are asked to perform all of them.

4.1 Results from Study 1

The study was participated by 22 bachelor and master students with different backgrounds in game development, education, and sports sciences. A comparative analysis was made to detect differences in the participants' responses before and after playing the proposed game-based methods.

We have performed a content analysis on the answers to both pre-and post-questionnaires. The answers to domain-general and domain-specific creativity questions have been analysed to quantify word frequency and identify relevant subjects and concepts. The answers to the questions about creative self-efficacy and belief in creativity training have been ranked by their Likert-scale score. The solutions presented to the domain-general creativity exercise have been quantified according to their assigned originality, fluency, flexibility, and elaboration scores. This analysis has been contrasted with the observer notes on the participants' performance in the game-based experiences.

For the domain-specific question, participants were noticeably more eloquent during the post-test, with an increase of 20.12% and 46.66% in words and sentences, respectively, in their answers. There were 3 empty answers in the pre-test, whereas all participants responded in the post-questionnaire. Answers in both pre-and post-tests relate to one of the following topics: "disguise taste", "make a challenge/game", "nutrition facts", and "one-in-a-lifetime experience". Another category of answers was only found during the post-test: "Offer a reward". Similarly, the responses to the domain-general question contained up to 15,78% more words in the post-test. The answers to the questions in creative self-efficacy and belief in creativity training showed almost the same distribution of Likert scores in all questions on both occasions.

Participants showed increased overall performance in the post-test group domain-general exercise with 24 different uses with an average aggregated score of 7.91 in the post-test (20% and 20,76% increase from the pre-test, respectively). The category that the experiment showed the highest increase (25%) was originality. No uses in the pre-test scored higher than 9 in total, whereas 6 uses in the post-test scored at least 10, being 18 the highest aggregated score.

4.2 Discussion

Study 1 analyses the capacity of the proposed methods to get participants ready for embodied creativity, supporting them in getting into the right mindset to later engage in embodied and movement-based activities. It doesn't aim to analyse participant performance at exerting creativity but focuses on whether participants' readiness to exercise their body-creativity increases after the proposed warm-up session.

Results show that participants' answers were more diverse after the exercises under the same conditions and time limit. The domain-general group exercise showed that participants' readiness to design, act, and perform with their bodies was higher after playing social videogames. On the contrary, participants' perceptions of their creative skills remained unchanged after the experimentation.

The observations were taken during the session point that the participants engaged smoothly with the proposed team activities, despite having a cold start with no previous exercises or preparation. A relaxed and fun environment invited participants to socialise and motivated their curiosity to enjoy the exercises, cooperating and competing where appropriate. These are desirable characteristics of warm-up and ice-breaking activities.

5. Studies 2 and 3: Facilitating the Game-Based Methodology

Studies 2 and 3 aim to understand how external instructors could better facilitate the proposed method. To these aims, the experimental setting now adds the role of facilitators to the existing roles of participants, observers, and chairperson. In both studies, a group of students are invited to participate in a single session like the one in the first study, though in this case, the students are taking a course in which they are tasked with an embodied design assignment. The course lecturers participate in the session as facilitators, becoming the test subjects. The session has been arranged to serve the students as a warm-up session to prepare them for their embodied design assignment.

5.1 Study 2: Facilitation Without Previous Training

The session lasted for 5 hours, with a total of 29 students in Interaction Design as participants, and three teachers as facilitators, experts in teaching embodied and interaction design. As in the previous case, the study counts on a chairperson and two observers. Verbal informed consent was obtained from the participants, who could withdraw at any moment.

Participants arrived at the session without any prior instructions or information about the game-based experiences. Both facilitators had been verbally informed about the methodology and the composing games in a short meeting before the session. Still, they hadn't tried any of the experiences themselves and declared not to have previous experience with the included games. The session used the four experiences, which were illustrated by their accompanying mood-setting cards (Figure 2), made available for the facilitators to use at their own discretion.

Facilitators were asked to fill out an online post-questionnaire (Font & Johnsson, last accessed May 2023) to obtain qualitative data from experts when facilitating the methodology during a session integrated into a course, but without receiving any prior training about it.

5.2 Results from Study 2

We have performed a content analysis on the answers to the questionnaire to extract the most relevant and frequently repeated concepts and topics. This has been matched with the observation notes taken during the experiment, to determine when concepts were noticed from either one or both ends (participant and observer).

Facilitators agreed on that the proposed method can't be used without previous preparation. They asked the chairperson several times for help, both with technical questions about how to operate the games and understanding the modified gameplays. This matches the notes from the observers. Their perceptions on the participants highlight that students had to invest some time at the beginning into understanding some of the modified gameplays, which took some time from them before they started engaging fluently in the group dynamics. However, facilitators and observers noted that all participants enjoyed all activities both socially and individually.

Facilitators perceived that the method gave participants a playful framework to temporally get away from their assignment to experiment with embodied design ideas freely. They positively valued the competition and passion elicited by the social gameplay, as well as how it let them carelessly inhibit any social pressure or prejudice to be able to feel comfortable while exposing their body movements.

Facilitators and students initially consulted the method cards, but both soon discouraged them and remained unused during the session. It was noted that the cards demand time and concentration to be read through and understood, whereas the session is unsuitable for focused reading.

The method was deemed very suitable to become part of an educational setting as a warm-up activity for courses focusing on innovation, interaction design, and bodystorming. The main noted advantages of such a scenario were students gaining insights on their current course learning, the opportunity for the students to switch to an explorative context where they experiment with their body creativity, and a framework where social interactions are fostered to favour student teambuilding.

5.3 Study 3: Facilitation After Previous Training and Planning

This third study was motivated by the takeaways from study 2 regarding lack of previous preparation. The experimental setup was modified to address this issue, adding two previous meetings where two facilitators (who already participated in study 2) had the chance to use materials in the MeCaMInD toolbox to discuss and design the composition of the experimental session. The materials used were the four method cards used in study 2 (Figure 2), plus the complete set of modifier cards available in the toolbox (Figure 3). Having in mind their knowledge about the four game-based experiences and the cards, the facilitators first filtered out the modifiers that didn't suit the game-based mood-setters, to then design a session with only two of the available games (Copy Dance and Johann Sebastian Joust), and two sets of modifiers tailored to each of them. They planned to have the session as part of a master course, as a training session for one of the course projects.

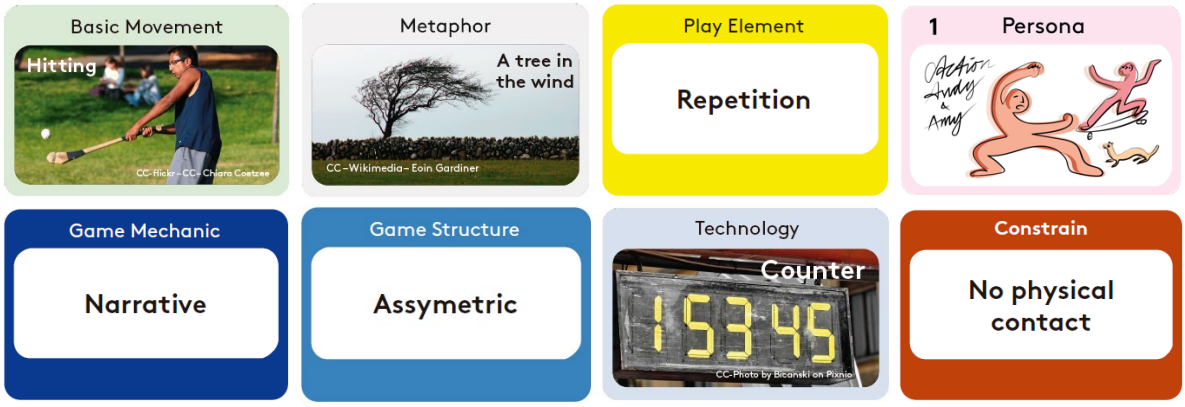

Figure 3: Sample modifier cards (8 out of 284) belonging to 8 different categories (among 16 available)

The session lasted two hours, with 8 master students as participants, two facilitators, one observer and a chairperson. The facilitators were instructed that the chairperson would only mediate to solve technical issues with the involved materials but wouldn't intervene to give methodological support. After the participants played the two selected games during the first hour, an open interview was conducted during the second half of the session. Both facilitators were asked to complete an online post-questionnaire (Font & Johnsson, last accessed May 2023). The video was recorded during the whole session, and written informed consent was obtained from all participants.

5.4 Results from Study 3

Like Study 2, we performed a content analysis on the answers to the questionnaire and matched the extracted concepts with the observation notes. Additionally, a two-fold analysis has been performed in the recorded video. The first half of the video, related to participation in the game-based experiences, was analysed to identify patterns in how facilitation was carried out and how participants performed in the experiences. A narrative analysis has been performed on the second half of the video, on the open interview, to extract results on how relevant concepts were perceived from the perspectives of both facilitators and participants.

Answers confirmed that this time, the facilitators knew enough about the toolbox's resources to properly organise the session and integrate it as part of the course. This experimental setup allowed us to get insights from the facilitators on the cards, which were deemed comprehensive and interesting to explore embodied interaction. It was suggested that having sample implementation cases for inspirational purposes on using the cards would be an interesting additional resource.

The facilitators' answers to the game-based experiences were much more detailed in this case, with specific insights on each game and their expected outcome in combination with several modifier cards. Mood-setting cards were deemed useful only during the preparation session. In contrast, modifiers were used both for preparation and during the experimentation as a resource for facilitators to add variety to the gameplay as the session progresses dynamically. Other props available in the room, like furniture, were punctually added by the facilitators to foster participants' awareness of their body movements. This denotes a higher degree of familiarity with the methodology that allowed facilitators to experiment fluently with other available resources at their own will.

Facilitators started both game experiences by showcasing how to play in the standard and modified gameplays. No major issues were reported, and the chairperson only intervened once when one participant accidentally exited a game to the main menu.

Participant engagement was reported in high grade, as in the former study, though now students asked for feedback on their body moves and expressions, actively reflecting and discussing on what they intended and eventually communicating with them. One facilitator noted that some participants were too focused on playing the activity as intended to the detriment of a playful environment where students could freely experiment with their creativity.

5.5 Discussion

Studies 2 and 3 suggest that the proposed methodology can't be expected to be handled by facilitators by a straight out-of-the-box approach. Without proper preparation, participants seem to engage well with the proposed games, which easily elicit a relaxed and playful environment to break the ice and invite participants to perform body movements. Nevertheless, neither facilitators nor learners can be expected to be familiar enough with the materials used for the experience to be fruitful as a warm-up for embodied design. Results show that the optimal minimal configuration requires one person with experience in MeCaMInD's toolbox to guide the facilitator during the first contact with the proposed method and games, followed by a discussion where the facilitator is assessed on how to integrate it as part of an extended learning activity with the support of the mood setting and modifier cards. Results from Study 3 show that a whole session can be run entirely by a facilitator without the need for a chairperson. They also suggest that MeCaMInD's toolbox works well as a resource for planning, adapting, and integrating the methodology as part of a course or assignment.

6. Conclusions and Future Work

This paper proposes a game-based methodology as warm-ups for embodied design, using off-the-shelf materials commonly available at stores. The social and playful nature of these games makes the proposed method reach out to a very broad set of users, who can easily become familiar with and engage well with the group activities regardless of their background. The proposed twisted gameplays make them suitable to exert body moves and get ready to think and design with their bodies.

The studies on facilitation pointed out the need for a preparation session supported by someone with previous experience using MeCaMInD's toolbox. Nevertheless, results show that one introductory session is enough for the toolbox to become an easily configurable resource that adapts to the facilitator's needs and goals, highly customisable with the use of the modifier cards and inviting to extend it with extra props.

Results from Study 1 show that using games as warm-ups for embodied design is promising. Still, this approach needs to be validated at larger scales as a recurrent instrument in extended periods of time (i.e., a repeated activity throughout a course), allowing separate pre-and post-tests to eliminate any potential influence on one another. Extended studies will also allow us to evaluate these contributions in combination with the method and concept cards in MeCaMInD and different application domains.

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Designing Educational Escape Rooms With Generative AI: A Framework and ChatGPT Prompt Engineering Guide

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Abstract: Generative Artificial Intelligence (GenAI) holds the transformative potential to reshape education, particularly in the domain of content creation. One promising application lies in the development of educational escape rooms (EERs) which are increasingly adopted to foster active, experiential learning, critical thinking, and collaboration. Nevertheless, crafting effective EERs tailored to specific learning contexts often poses a daunting and time-consuming challenge. This paper explores the dynamic synergy between Room2Educ8, a framework rooted in Design Thinking principles, and the publicly accessible AI tool ChatGPT. Room2Educ8 provides a structured methodology encompassing vital steps like empathising with learners, defining learning objectives, weaving narratives, devising puzzles, briefing and debriefing participants, prototyping, and evaluating the EER experience. Complementing this framework, the paper presents a collection of sample prompts that illustrate ChatGPT's pivotal role within the EER creation process. By offering innovative ideas, suggestions, and content, these prompts not only expedite ideation and concept development but also simplify prototype creation for testing and refinement. This streamlining process reduces cognitive load, freeing educators to focus on higher-level considerations. The primary contribution of this paper lies in its harmonious fusion of ChatGPT with a structured design framework, effectively demystifying the EER creation process. With its practical guidance, including a prompt engineering guide, it extends the accessibility of EER design to a wide spectrum of educators, encompassing those with limited prior exposure to the intricacies of escape room formats. Beyond its immediate benefits, this paper serves as a gateway to future research prospects within the domain of AI-powered educational experiences, marking a step towards realising the potential of AI in the field of game-based learning.

Keywords: Educational escape room, Generative artificial intelligence, ChatGPT, Design thinking, Game-based learning

1. Introduction

Escape rooms (ERs) are emerging as a novel genre of learner-centric activities meticulously crafted to amplify students' educational progression and foster the cultivation of 21st-century proficiencies across primary, secondary, and tertiary academic settings, as well as within programs dedicated to professional development (Guckian et al., 2020; Sanchez & Plumettaz-Sieber, 2018; Adams et al., 2018). An educational escape room (EER) is an innovative pedagogical concept wherein participants, typically students, engage in a purposefully designed immersive environment filled with puzzles, challenges, and riddles that are linked to unambiguous learning objectives. The primary objective of an EER is to facilitate active and experiential learning through problem-solving, critical thinking, collaboration, and content assimilation (Fotaris & Mastoras, 2019).

EERs can harness the advantages encompassing "competition, adversity, creative thinking, comprehensive environmental exploration, attainment of objectives, diverse interpersonal and object-related engagements, and assurance of safety" (Guignon et al., 2018). The puzzles embedded within EERs are rooted in problem-solving paradigms, necessitating proficient communication and collaborative aptitudes, aspects inherently integral to the adult learning process (Jennings et al., 2013). Moreover, a sturdy narrative framework assumes the role of establishing the backdrop, while reflective activities after the game contribute to the reinforcement of educational aims. EERs can also incorporate puzzles, challenges and scenarios that draw inspiration from diverse cultural backgrounds, thereby facilitating the cultivation of cross-cultural understanding and appreciation (Fotaris & Mastoras, 2022).

These benefits have contributed to the adoption of EERs to introduce, foster, demonstrate, assess, or integrate students' content knowledge and skills into a wide variety of academic disciplines (Veldkamp et al., 2020). In creative courses, students have been asked to become "makers" and develop EERs as a means to demonstrate and improve their creative, artistic, and design skills so that they can come up with innovative solutions to problems (Ma et al., 2018; Li et al. 2018). Additionally, EERs can be used for inductions in a variety of ways, such as introduction to company culture, policies, procedures, and values, orientation to the workplace, safety training, team building, and technical training (Fotaris & Mastoras, 2022).

Researchers have begun to build upon the notion of teachers as designers of learning experiences for students (Elwood et al., 2016). EERs offer the prospect of ushering in novel pedagogical methodologies, as demonstrated by the exponential surge in scholarly works exploring the incorporation of escape rooms within educational frameworks. Nonetheless, the intricate development and meticulous design of EERs that cater to distinct learning contexts necessitate a substantial investment of time and dedication. This is particularly true for educators who may lack prior expertise in game design (Fotaris & Mastoras, 2022), and consequently, might encounter challenges in making effective decisions regarding various aspects of EER design. These may include group size, contextual relevance, time constraints, rules, narrative, and puzzles – all of which intricately shape the learning experience (Taraldsen et al., 2022).

One possible strategy to tackle this issue involves employing a framework uniquely crafted to provide educators with direction in the creation of robust and impactful EER experiences. This is achieved through the utilisation of generative artificial intelligence (Gen-AI) systems, which can produce a wide range of outputs, such as texts, images, videos, or code, by employing a data repository that trains them (Sánchez-Ruiz et al., 2023). Arguably, one of the most popular AI technologies used to facilitate learning within the educational context is the Chatbot system (Clarizia et al., 2018), a conversational or interactive agent that provides instant responses to the user (Okonkwo & Ade-Ibijola, 2021), exemplified by OpenAI's well-known ChatGPT tool (OpenAI, 2023). It has an unprecedented ability to carry out remarkably complex tasks like writing an article, story, poem, an essay, summarising or expanding a text, adjusting texts to reflect a different perspective, and even writing and debugging original computer code (Baidoo-Anu & Owusu Ansah, 2023; Taecharungroj, 2023), thus becoming an essential academic tool for students in higher education (Jishnu et al., 2023).

The present paper is a continuation of a longitudinal project about EER design; it delves into a deliberate exploration of how ChatGPT's functionalities can be strategically harnessed during the development of EERs to offer time-saving, idea-generating, and customisable assistance, thus allowing designers to create more engaging and effective educational escape rooms. This is accomplished through the integration of Room2Educ8, a user-centred conceptual framework that derives its foundation from design thinking principles. Notably, Room2Educ8 offers a versatile structure that can be flexibly tailored to various subjects, learning goals, and class sizes (Fotaris & Mastoras, 2022). The core focus of this article revolves around a description of each stage of Room2Educ8, subsequently enabling straightforward application, followed by the provision of specialised prompts designed for employment alongside ChatGPT. These prompts are curated to elicit content generation corresponding to each unique stage encapsulated within the Room2Educ8 framework, including learner personas, learning objectives, S.M.A.R.T. goals, stories, puzzles, clues, hints, game rules and instructions, briefing and debriefing scripts, surveys, interview questions, and evaluation plans.

2. Background

ChatGPT, introduced by OpenAI in November 2022, marks a significant advancement in the field of natural language processing (NLP). Its primary purpose is to comprehend and generate text that closely resembles human language in response to input queries. This capability positions ChatGPT as a versatile tool for a wide range of NLP tasks (Thompson, 2022). Despite sharing a foundation with other Large Language Models (LLMs) and generative pre-trained transformers, ChatGPT distinguishes itself through its unique combination of free accessibility, user-friendly interface, and advanced response generation capabilities (Tate et al., 2023). As a result, it swiftly garnered attention and adoption across various domains. Remarkably, within its first week of launch, ChatGPT acquired an impressive one million users (Mollman, 2022), and in under two months, this number surged to over 100 million active users (Hu, 2023).

ChatGPT belongs to the class of generative language models, built upon the architecture of GTP-3.5 and GPT-4 – members of OpenAI's proprietary series of generative pre-trained transformer (GPT) models. Its latest version ChatGPT Plus reportedly comprises eight models, each with an unprecedented 220 billion parameters. The total parameter count of GPT-4 is estimated to be around 1.76 trillion, making it the largest language model ever created (Lubbad, 2023). Its training data draw from a vast and diverse corpus of internet text, endowing ChatGPT with extensive knowledge encompassing language, facts, and context.

In the realm of education, ChatGPT proves transformative. Its applications include creating virtual tutors, addressing student queries, and tailoring personalised learning experiences. It aids educators in teaching and student assessment, offering recommendations for designing more inclusive and accessible learning activities (Denny et al., 2023). Furthermore, recent research has explored integrating language models into game design processes. Zhu and Luo (2022) employed a generative approach, combining a language model with a knowledge base of existing patents to generate innovative design ideas. Van Stegeren & Myśliwiec (2021) used GPT-2 to

craft dialogues for non-player characters in role-playing games, while Värtinen et al. (2022) applied GPT-2 and GPT-3 to describe quests in similar gaming contexts. Frans (2021) introduced a framework for building Language Model Games, where players manipulate a language model to achieve desired in-game behaviours, as demonstrated in the "AI Charades" demo. In parallel, Charity et al. (2023) employed GPT-2 to suggest game features based on textual prompts. Additionally, Lanzi et al. (2023) proposed a collaborative design framework, blending interactive evolution with ChatGPT to simulate human design processes. This collaboration involves humans and LLMs recombining and transforming ideas, using genetic algorithms for complex creative tasks.

In the realm of game-based learning, though, the incorporation of AI-based systems into teaching and learning is still relatively unexplored by educators. This uncertainty stems from a lack of familiarity and limited experience in using AI to enhance the student learning process, as highlighted by Lameras (2023). Additionally, a comprehensive framework that utilises LLMs in the creation of EERs has yet to emerge. The present paper addresses this gap by presenting a well-structured guide for seamlessly integrating ChatGPT into the Room2Educ8 framework. This guide is a valuable resource designed to assist researchers, educators, and developers interested in crafting immersive and educational escape room experiences.

3. Using ChatGPT With Room2Educ8: A Practical Guide

Room2Educ8 (Figure 1) is a conceptual framework specifically designed to offer educators guidance in creating robust EER experiences and has been developed iteratively with pilot testing and refinements of individual elements since 2018 (Fotaris & Mastoras, 2022). It is based on design thinking, a process that has already been used as an instructional design method for the development of course content or teaching material (Sheehan et al., 2018), in curricular development (Habbal, 2016), and as a teaching strategy to achieve subject-specific learning goals (Panke, 2019).

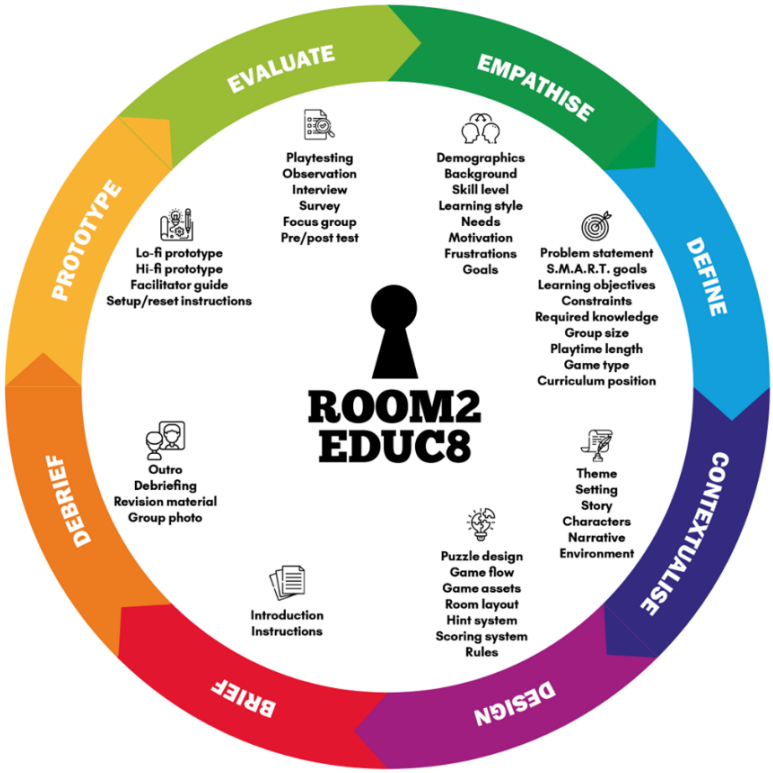
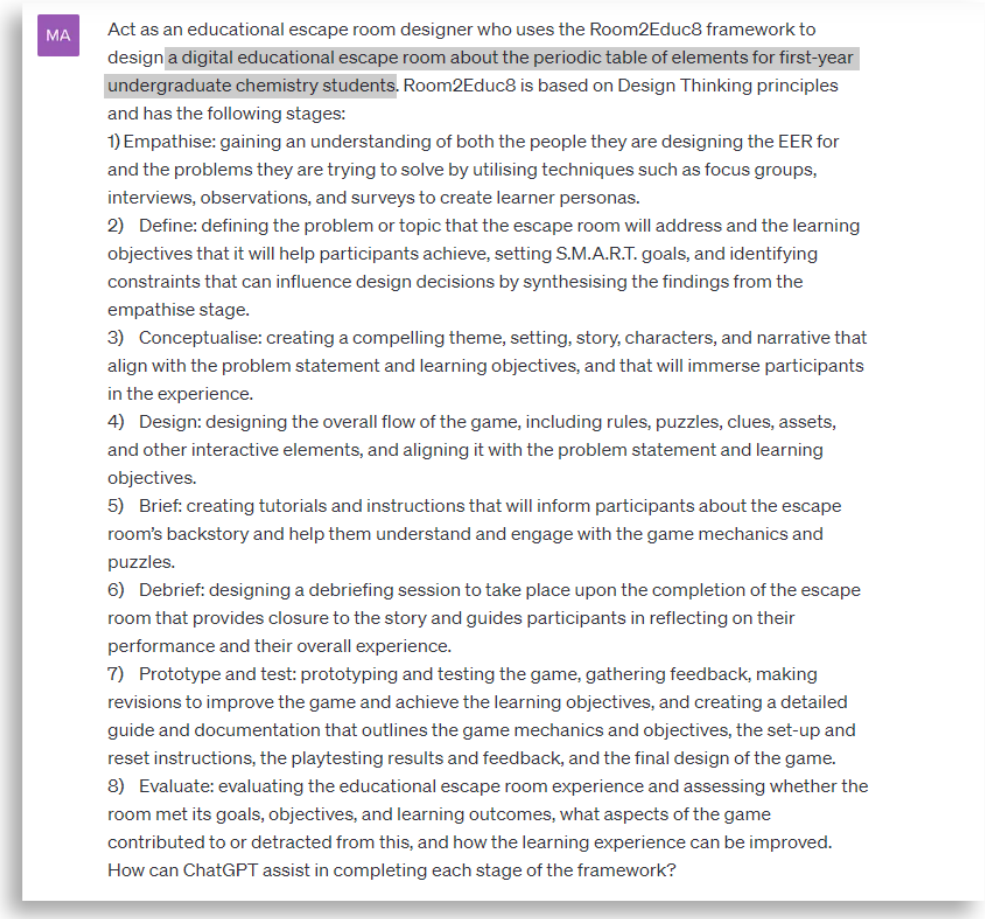


Figure 1: Room2Educ8 framework

Room2Educ8 enables EER designers to utilise ChatGPT as a powerful tool for generating ideas across every stage of the framework. This integration ensures consistency throughout the entire project journey. In this context, the ChatGPT input prompt holds a crucial role as it acts as an instruction or topic given to the LLM, guiding its response by establishing the conversation context and specifying the essential information and desired output format and content (Liu et al., 2023). The "Act as a..." command allows users to specify a persona or character for ChatGPT to adopt during a conversation or toward a particular outcome. Prompt engineering, i.e., the practice of designing and refining prompts to elicit specific responses from AI models, can be a challenging task, as the quality of the AI's responses depends on the precision and clarity of the instructions provided (White et

al., 2023). To overcome this challenge, designers should initially acquaint ChatGPT with Room2Educ8 by offering a concise overview of each stage. This preliminary step ensures that the AI tool comprehends the framework, enabling it to generate relevant responses to the prompts posed by designers. An initiating prompt of the chat that introduces Room2Educ8 to ChatGPT and also provides insights into how ChatGPT can support each framework stage is presented in Figure 2.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Act as an educational escape room designer who uses the Room2Educ8 framework to design a digital educational escape room about the periodic table of elements for first-year undergraduate chemistry students. Room2Educ8 is based on Design Thinking principles and has the following stages:
1) Empathise: gaining an understanding of both the people they are designing the EER for and the problems they are trying to solve by utilising techniques such as focus groups, interviews, observations, and surveys to create learner personas.
2) Define: defining the problem or topic that the escape room will address and the learning objectives that it will help participants achieve, setting S.M.A.R.T. goals, and identifying constraints that can influence design decisions by synthesising the findings from the empathise stage.
3) Conceptualise: creating a compelling theme, setting, story, characters, and narrative that align with the problem statement and learning objectives, and that will immerse participants in the experience.
4) Design: designing the overall flow of the game, including rules, puzzles, clues, assets, and other interactive elements, and aligning it with the problem statement and learning objectives.
5) Brief: creating tutorials and instructions that will inform participants about the escape room's backstory and help them understand and engage with the game mechanics and puzzles.
6) Debrief: designing a debriefing session to take place upon the completion of the escape room that provides closure to the story and guides participants in reflecting on their performance and their overall experience.
7) Prototype and test: prototyping and testing the game, gathering feedback, making revisions to improve the game and achieve the learning objectives, and creating a detailed guide and documentation that outlines the game mechanics and objectives, the set-up and reset instructions, the playtesting results and feedback, and the final design of the game.
8) Evaluate: evaluating the educational escape room experience and assessing whether the room met its goals, objectives, and learning outcomes, what aspects of the game contributed to or detracted from this, and how the learning experience can be improved.
How can ChatGPT assist in completing each stage of the framework?

Figure 2: Initiating prompt

Tables 1-8 comprise exemplar ChatGPT prompts intended for use in conjunction with each Room2Educ8 stage to aid in the development of an EER. These prompts are intentionally open-ended and adaptable to cater to users' preferences and interests. Their primary purpose is to elicit ChatGPT responses that serve as initial reference points for EER design, offering innovative ideas, suggestions, and content that designers might otherwise overlook. This not only saves substantial time during the ideation and concept development phases but also streamlines the early stages of EER design by simplifying the creation of prototypes for testing and refinement. Consequently, designers experience a reduced cognitive burden, allowing them to concentrate on higher-level considerations, such as defining learning objectives and optimising the user experience. After the initial generation of concepts and content, designers have the opportunity to delve deeper into the ideas presented in ChatGPT responses. They can enhance these concepts with their unique creative input by crafting follow-up queries to ChatGPT that align with their original prompts. This process facilitates the development of more intricate narratives, puzzles, and engaging interactive elements. Furthermore, certain sample prompts play a crucial role in upholding consistency in storytelling, character development, and thematic elements within the entire EER. In contrast, other prompts can aid in the creation of survey questions or feedback forms for playtesting, simplifying the data collection process and ensuring thorough feedback. While it is essential to acknowledge that ChatGPT's responses are generated by AI and may not invariably align precisely with designers' expectations, they nonetheless represent a valuable source of inspiration and an effective starting point for the creative process.

Table 1: Ways ChatGPT supports EER designers in Room2Educ8's Empathise stage

Aim	Sample prompt
Generate interview and/or survey questions to gather insights about your target audience's interests, preferences, and learning styles.	"Write [*n*] interview questions to understand the preferences and learning styles of the [*target audience*]."
Suggest techniques for conducting effective focus groups.	"Give me ideas on how to conduct engaging focus groups to gather insights."
Summarise the collected data.	"Summarise the key findings from the participant survey."
Provide templates for creating learner personas to represent the target audience's characteristics and preferences based on the collected data.	"Write a detailed learner persona for [*a first-year undergraduate art student*] who [*has little knowledge of the Bauhaus art school and its impact on art and architecture*]. "

Table 2: Ways ChatGPT supports EER designers in Room2Educ8's Define stage

Aim	Sample prompt
Generate problem statements based on the information gathered in the empathise phase.	"Using the information gathered from the focus group and survey, create a problem statement for the educational escape room that highlights the gap in understanding we aim to address and the learning objectives we hope to achieve."
Generate learning objectives based on the problem statement and the information gathered in the empathise stage.	"Create a list of [*n*] measurable and specific learning objectives that align with the identified gap in understanding and the problem statement developed in the previous step."
Assist in formulating S.M.A.R.T. goals for learning objectives.	"Create a list of [n] specific and measurable goals for the escape room's learning objectives."
Create a list of constraints that might impact design decisions.	"Create a list of [n] constraints that must be considered when designing the educational escape room."
Define the required knowledge.	"Create a list of the specific knowledge and skills required for participants to complete the escape room."

Table 3: Ways ChatGPT supports EER designers in Room2Educ8's Contextualise stage

Aim	Sample prompt
Brainstorm immersive themes and narrative concepts.	"Write [*n*] story ideas for themes and stories that align with the learning objectives. Think outside the box and come up with something unusual and original."
	"Using the [*ChatGPT-generated theme and story*], write a detailed plot that aligns with the learning objectives."
	"Develop [*n*] intriguing characters that will captivate participants."
	"Create a narrative that provides context and relevance to the puzzles and challenges."
	"Develop a detailed description of the room layout and game assets that will be used in the escape room, considering the constraints identified in previous steps."

Table 4: Ways ChatGPT supports EER designers in Room2Educ8's Design stage

Aim	Sample prompt
Suggest puzzle ideas that align with learning objectives.	"Write [*n*] puzzle ideas that align with the [*learning objectives*] and suggest ways to tie them into the narrative."
Create clues and hint systems.	"Create a hint system for the [puzzle]."

Aim	Sample prompt
Create a balanced flow of puzzles and interactive elements.	"Create a game flow for the escape room."

Table 5: Ways ChatGPT supports EER designers in Room2Educ8's Brief stage

Aim	Sample prompt
Generate written or verbal instructions for the participants.	"Create a clear and concise outline of the escape room's objectives, rules, and hints."
Create engaging scripts for the briefing video.	"Write a script for an engaging and informative briefing video, which provides participants with a clear understanding of the escape room's backstory, objectives, and rules, while also immersing them in the experience and motivating them to complete the game by highlighting the stakes and rewards of success."
Create an in-game tutorial that helps participants understand the game mechanics and objectives.	"Write an in-game tutorial that guides players through the game mechanics, including information on how to navigate the room, solve puzzles, and access hints."

Table 6: Ways ChatGPT supports EER designers in Room2Educ8's Debrief stage

Aim	Sample prompt
Wrap up the game with a satisfying ending.	"Suggest ways to wrap up the escape room experience with a satisfying ending."
Create an engaging script for the outro video	"Write the script for an engaging and informative outro video that summarises the key learning objectives and provides participants with a sense of accomplishment and closure. The video should align with the theme, setting, plot, and characters developed in previous steps."
Produce a debriefing guide	"Write a debriefing guide that includes [*n*] discussion prompts and reflection questions to help players reflect on their experiences and the learning objectives achieved during the game."

Table 7: Ways ChatGPT supports EER designers in Room2Educ8's Prototype and Test stage

Aim	Sample prompt
Provide a checklist for playtesting, along with guidance on gathering meaningful feedback.	"Write a detailed testing plan that outlines the steps to be taken during the prototyping and testing phase, including a list of tasks, responsibilities, and timelines." "Create a checklist for playtesting the escape room and gathering meaningful feedback."
Create a facilitator guide.	"Write a list of setup and reset instructions for the escape room facilitator."
Assist in refining the escape room design based on playtest feedback.	"How can I incorporate playtest feedback to improve the overall escape room experience?"
Provide tips for creating comprehensive documentation for the game.	"What should I include in the documentation to guide setup, gameplay, and reset instructions?"

Table 8: Ways ChatGPT supports EER designers in Room2Educ8's Evaluate stage

Aim	Sample prompt
Suggest criteria for evaluating if learning objectives were met.	"What factors should I consider when assessing whether the escape room achieved its educational goals?"
Provide ideas for gathering participant feedback on the experience.	"How can I get constructive feedback from participants to evaluate the escape room's effectiveness?"

Aim	Sample prompt
Create a post-game survey/feedback form.	"Create a post-game survey to be distributed to participants immediately after they complete the escape room. Use a combination of [*n*] closed-ended (quantitative) and open-ended (qualitative) questions to gather both numerical ratings and detailed comments."
Write post-game interview questions.	"Write a script for a post-game [interview type] interview to measure the effectiveness of the escape room in achieving its learning objectives and gather feedback on the game mechanics, puzzles, hint system, and any other elements of the game that could be improved in the future."

4. Use Case

To ensure ChatGPT's ability to assist in the creation of an EER, a set of prompts was crafted, aligning with each phase of the Room2Educ8 framework. The AI-generated responses informed the design of a digital EER about the periodic table of elements, specifically designed to captivate the interest of first-year undergraduate chemistry students. Presented below are a few selected prompts that were employed during the Contextualise and Design stages (Figure 3):

- "Come up with 10 story ideas for an EER about the periodic table of elements, the atomic weight, and the atomic number Think outside the box and come up with something unusual and original."
- "Come up with more unusual ideas that haven't been done so often before."
- "What locations can we use for the Atomic Art Heist?"
- "What items could we find in the Art Gallery in a Haunted Mansion?"
- "Give me 3 puzzles that need to be solved in the Art Gallery in a Haunted Mansion that cover the learning objectives of understanding the periodic table of elements, the atomic weight, and the atomic number. The puzzles should make use of the items found in the Art Gallery in a Haunted Mansion."
- "Rewrite the previous puzzles, using the following format: puzzle title, learning objective, description, clues, location, solution."
- "Create a hint system for each one of the 3 puzzles."
- "Using the Art Gallery in a Haunted Mansion, generate a detailed plot and character descriptions that align with the puzzles."
- "Write a detailed description of the room layout and game assets that will be used in the educational escape room."
- "Using the theme, setting, plot, and characters developed in previous steps generate a script for a video introduction that sets the stage and provides background information for the educational escape room."
- "Write an in-game tutorial that guides players through the mechanics of the educational escape room, including information on how to navigate the room, solve puzzles, and access hints and clues."
- "Write the script for an engaging and informative outro video for our educational escape room, which summarizes the key learning objectives and provides players with a sense of accomplishment and closure. The video should align with the theme, setting, plot, and characters developed in previous steps and effectively reinforce the importance of the mission the students just completed and their role in it."
- "Create a game flow for the educational escape room."

All prompts were crafted following a foundational set of prompt engineering principles. Foremost among them was the emphasis on clarity and specificity, ensuring that each instruction was initiated with a clear and precise directive. To personalise responses, the persona of an EER designer was designated for ChatGPT to embody, tailoring its interactions accordingly. Furthermore, maintaining alignment with the EER's learning objectives was essential to ensure that the prompts effectively supported the educational goals. The active use of feedback loops allowed for prompt refinement, resulting in iterative improvements. Contextual clarity was incorporated when needed to guide the AI's output effectively. Additionally, real-life scenarios were utilised for certain prompts, grounding them in practical and relatable situations.

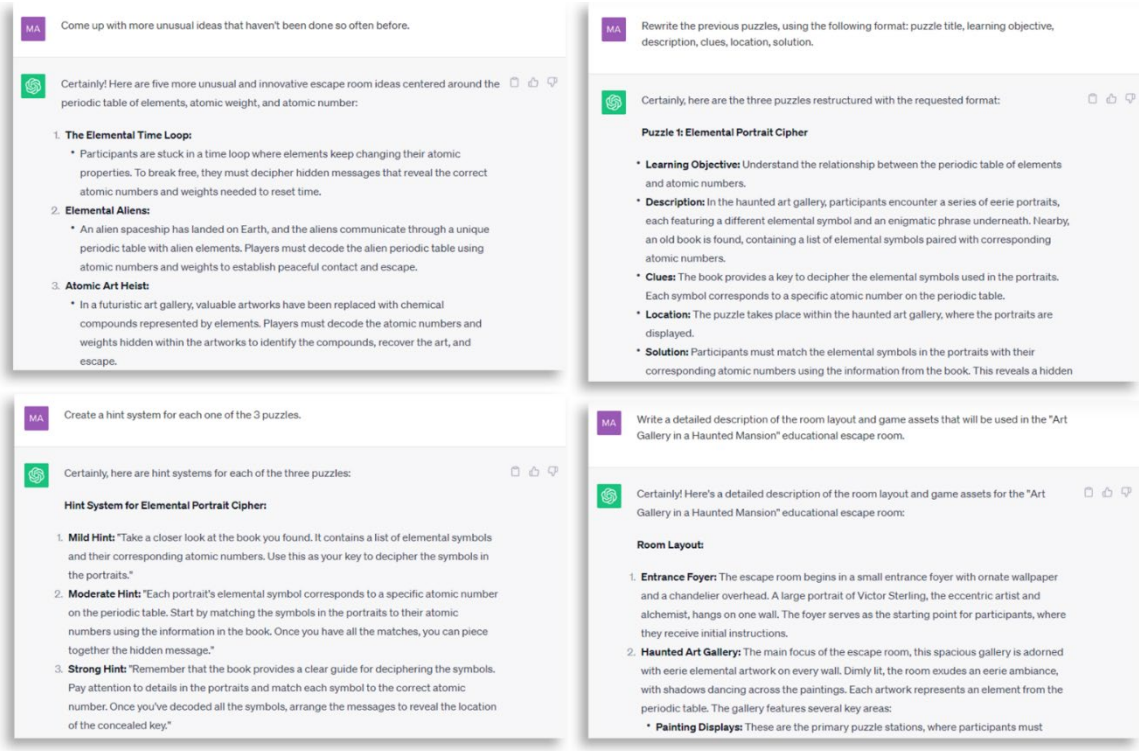

Figure 3: Prompts used during the Contextualise and Design stages

5. Conclusion and Future Work

Room2Educ8 simplifies the process of aligning learning objectives with puzzles and narratives, resulting in a cohesive and immersive interactive story that enhances learning experiences (Fotaris & Mastoras, 2022). The decision to integrate this framework with ChatGPT stemmed from the goal of making EER design more accessible to educators, especially those lacking prior experience with escape room formats or facing time constraints. ChatGPT's user-friendly interface requires no specialised technical skills, ensuring educators with varying levels of tech proficiency can benefit. Additionally, ChatGPT's quick content generation reduces the time educators spend on content creation, allowing them to focus on essential aspects of teaching and learning. The included prompt engineering principles provide a valuable reference for crafting effective prompts, while the sample prompts can be easily adapted to various subjects, significantly improving the efficiency and effectiveness of the EER development process.

One limitation of this study is the restricted testing of the digital prototype by students, primarily due to time constraints. Subsequent efforts will involve the development and thorough assessment of EERs designed with Room2Educ8 and ChatGPT to scrutinise their impact on the overall learning experience. Additionally, a follow-up study is planned, wherein Education students, pre-service teachers, and professionals in the education sector will utilise Room2Educ8 and ChatGPT to design EERs. Their feedback and responses to the proposed framework will be systematically recorded and analysed.

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Teaching GBL Principles to Japanese Students of Education in an EFL Setting

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Abstract: A growing body of evidence shows that game-based learning (GBL) has become an invaluable tool for educators. Despite this fact, Japanese teacher training programs routinely ignore its inclusion. Aiming to address this issue, an innovative content language and integrated learning (CLIL) curriculum was developed in order to teach Japanese students of education the basics of GBL within their English communication classes. This paper presents a comprehensive account of the curriculum's development, the rationale behind it, and explores preliminary evidence regarding students' attitudes towards using GBL principles in their prospective teaching careers following course completion. A total of 147 students with English communication classes were included in the study, ranging from Common European Framework of Reference (CEFR) levels B2 to C1. Although exploratory in nature, early evidence suggests that after having undergone the course, students recognized the value of GBL principles and considered them useful for their future careers as educators. From an English as a Foreign Language (EFL) perspective, instructors observed that the method of teaching described herein fostered a livelier, more enthusiastic, and interactive learning environment compared to traditional EFL classrooms. These findings imply that GBL and game design principles might be useful to include in teacher-training programs, both in Japan and elsewhere.

Keywords: Content and Language Integrated Learning (CLIL), Game Based Learning (GBL), Task Based Learning (TBL), Games and Gaming, English as a Foreign Language (EFL), English as a Medium of Instruction (EMI), Curriculum development

1. Introduction

Due to the rapid development and adoption of digital technology over the last half decade, education has undergone unprecedented change (Saykili, 2019). New online platforms have enabled a more personalized and interdisciplinary approach towards learning (Walkington & Bernacki, 2020; Kopnina, 2020), which has led to a shift in the liberal arts in the direction of "global citizenship" and "sustainability" (Estelles & Fischman, 2020) as well as an increased focus on STEAM (Science, Technology, Engineering, Arts and Mathematics) subjects (Li et al., 2020). Meeting these changes in demand have been challenging for educators who are now expected to offer more to their students with fewer resources (Bottiani et al., 2019). This has inspired teachers to explore new pedagogical strategies such as task and project-based learning (Grossman et al., 2019), as well as various forms of multilingual instruction (Hu, 2023).

In Japan, these trends have now emerged in EFL classrooms, with many schools moving away from traditional forms of EFL teaching towards using English as a medium of instruction (EMI) within more complex content language and integrated learning (CLIL) curricula (Ikeda et al., 2021). An early example of this is Sophia University's *English for Academic Purposes (AEP)* program, which was first implemented in 2008 (2021). Today, most Japanese universities offer some form of CLIL-based "enrichment" within their curricula through either a "soft" or "hard" approach, where the former prioritizes instruction of the language elements over content (such as the case with Sophia University's *AEP* program), while the latter focuses almost exclusively on content with English being the medium of instruction (I.E. Japanese students studying biology in English). Generally speaking, in Japan, "soft" CLIL programs are directed towards lower-level EFL learners, whereas "hard" CLIL courses are designed with advanced EFL learners and/or international students in mind (2021).

Other inventive strategies currently being used to meet the demands of modern Japanese EFL learners include various forms of gamification and other game-based learning techniques (Freiermuth, 2022; Thanyawatpokin, 2022). Although this has been met with mixed reviews (Zhang etal., 2023), it is certain that Japan's enthusiasm for games and gaming shows no sign of decline (FreakOut Pte. Ltd., 2021). Thus, it is logical to expect continued demand for these techniques within educational settings in the future. In fact, early studies have shown that the majority of Japanese university students are receptive to the use of some form of gaming within their classes (Bolliger et al., 2015; Reinhardt, 2017).

2. Background

2.1 University of Teacher Education Fukuoka

This study was conducted at the University of Teacher Education Fukuoka (UTEF) in southern Japan, during the 2019 academic year. UTEF is committed to the promotion of educational research and the development of future teachers. Upon entry into the university, UTEF students have a clear goal of becoming nursery, elementary, junior or senior high school teachers. Although their subjects of specialty differ, they are all required to obtain four English credits before completing their degree. One of these mandatory courses is a first-year "English Communication" class. Often these classes employ traditional four-skills-based EFL methods of instruction, which can be rather repetitive for students who have previously undergone six years of secondary English education that utilize the same approach. Additionally, by the time they enter UTEF, most of these students have already obtained a level of English proficiency adequate for their career goals within the Japanese education system. In recognizing this situation, the authors of this study saw an opportunity to provide their students with more by drawing upon their wealth of knowledge and experience in both game design and education.

2.2 Game-Based Learning

Game-Based Learning (GBL) is an educational approach that incorporates gameplay strategies, rules, and social experiences into the learning context. It has gained significant attention in recent years due to the growing popularity of games and gaming, as well as its compatibility with various learning theories, including: Cognitive Learning Theory (Anderson, 1995), Constructivist Theory (Vygotsky, 1978), Social Learning Theory (Bandura, 1977), Socio-Constructivist Theory (Rogoff, 1990), Experiential Theory (Kolb, 1984), and Multiple Intelligence Theory (Gardner, 1983). This versatility allows GBL to engage cognitive processes such as problem-solving and decision-making (Gee, 2007), which empower learners to construct their own understanding (Squire, 2006). It fosters collaboration, communication, and competition, promoting social interaction and enhancing motivation (Clark et al., 2016). GBL creates immersive experiences that facilitate experiential learning and caters to diverse learning styles and intelligences (Plass, 2015). By incorporating GBL into teaching practices, educators can establish dynamic and effective learning environments, elevating student engagement and improving learning outcomes.

2.3 Game Based Learning as an Educational Tool

Within the field of education, there is a growing recognition of GBL as a powerful tool. Extensive research consistently demonstrates its ability to enhance engagement, provide opportunities for repetitive practice, heighten motivation, and deliver overall enhanced learning experiences (Adipat et al., 2021; Burguillo, 2010; de Freitas, 2018; Kapp, 2012 a & b; Lee et al., 2011; Nicholson, 2015; Randel et al., 1992). GBL has also been found to integrate effectively within task-based learning (TBL) frameworks, which are commonly used by EFL educators (York et al., 2018). Furthermore, contemporary game mechanics, including GMT games, wargames, and euros, show significant potential for educational purposes both in EFL contexts (2018) and beyond. This potential is exemplified by the use of GMT games in training intelligence officers (Ruhnke, 2017, 2018, 2020).

Unfortunately, despite the mounting evidence in support of the effectiveness of GBL, many attempts to incorporate games in the classroom still fall short due to the simplistic and repetitive nature of the games implemented (Blumenthal, 2009) or the dismissive belief that games are somehow "not serious" and therefore inappropriate in academic settings (Huizinga, 1955). This reflects an even broader issue, namely that educators have a limited understanding of the vast potential offered by modern gaming (Vlachopoulos et al., 2017). To address this issue, there is a pressing need to update the educational toolkit of students of education by introducing them to modern GBL principles and contemporary game design.

2.4 Selection of Game Design Principles

The selection of game design principles chosen for inclusion in the course curriculum was greatly influenced by Boller and Kapp's book, "*Play to Learn: Everything you Need to Know About Designing Effective Learning Games*" (2017). The book offers valuable insights, strategies, and practical guidance for creating engaging and impactful educational games. It covers various aspects of instructional game design, including game mechanics, learning objectives, assessment, and evaluation. The reason for choosing the principles outlined in Boller et al.'s book was their clarity and conciseness. Given the additional cognitive load on students who were learning through a second language, it was crucial for the researchers not to overcomplicate the instruction of GBL principles and game mechanics, which can often be complex. Boller et al.'s breakdown of these concepts provided a suitable

model that struck a balance between comprehensibility and complexity, ensuring an effective and manageable approach to teaching GBL principles and game mechanics within the curriculum design.

2.5 Bloom's Taxonomy and Curriculum Design

The CLIL-based course was designed to incorporate GBL principles to enhance the learning experience of Japanese students studying education in their second language (L2). To achieve this, a revised version of Bloom's Taxonomy (Bloom et al., 1956; Anderson et al. 2002) was used as a hierarchical framework for classifying learning objectives based on complexity and difficulty (see *Figure 1)*.

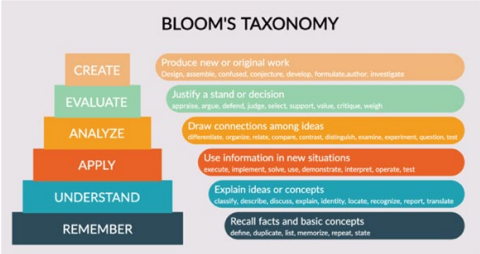

Figure 1: Bloom's Taxonomy

The decision to utilize Bloom's Taxonomy in the curriculum design was influenced by Krathwohl and Anderson's argument, that skills should take precedence over content, with content serving as a means to teach skills (2001). This aligns with the teaching philosophies of CLIL, which emphasize higher-order thinking skills found in the upper levels of the taxonomy. By incorporating the revised version of Bloom's Taxonomy, the curriculum aimed to strike a balance between evaluative and assessment-based questions and tasks, enabling students to engage in various levels of thinking while exploring and acquiring information.

In the classroom, a range of activities were implemented to apply the taxonomy effectively. Students were provided with opportunities to create original work, justify decisions, analyze connections among ideas, apply information in new contexts, explain concepts, and recall facts and basic concepts through gameplay. Additionally, students were asked to learn, play, and critique a selection of modern games that were carefully chosen to illustrate different aspects of game design. These activities correspond to different levels of Bloom's Taxonomy, allowing students to engage in diverse cognitive processes and utilize language effectively.

3. Methodology

3.1 Participants

The study included a participant sample of 147 students majoring in education at the University of Teacher Education Fukuoka. Among the participants, 107 first-year students enrolled in the course as a mandatory subject required for graduation, while 40 second-year students chose to take the course as an elective. The course was offered twice during the academic year, spanning both the spring and fall semesters of 2019. A detailed distribution of participants across these categories is provided in *Table 1*.

Table 1: Distribution of Participants

	1st year	2nd year	TOTAL
Spring	53	21	74
Fall	54	19	73
TOTAL	107	40	147

3.2 Content Selection

Within the board game community, there exist 191 recognized game mechanics (Board Game Geek, 2023), each offering a multitude of applications, variants, and opportunities for diverse themes and combinations. To mitigate the cognitive load on students who are already challenged by the CLIL-based design of the course, meticulous attention was devoted to the selection of mechanics explored throughout the program. These mechanics, along with the corresponding games used to illustrate them, were introduced in a progressive manner, gradually increasing in complexity (See *Figure 3a*). Consequently, the accompanying GBL principles and the related vocabulary and language necessary for their discussion also advanced in difficulty.

Individual lessons were based around a game (or a number of games) with a similar theme, design and/or mechanic. After teaching, learning and playing each game within a task-based learning (TBL) structure, students were asked to evaluate (using *Figure 3b*), then create their own variants of each game using the mechanics presented. The evaluations were collected and marked by the teachers for 1) language accuracy (grammar, punctuation, spelling, etc.) and 2) demonstration of content knowledge (how well they understood the mechanic introduced). The course culminated in a final project-based assignment, where groups of students were required to utilize game mechanics and GBL principles of their choosing in order to produce an original educationally-focused game, designed to teach subject-specific material to a designated level of learners (E.g. 8th grade Roman history).

Students were given four weeks to develop their games, moving through the individual stages of idea generation, content research, creation and play testing before finally presenting their games, complete with instructions and all the components required for game play (in English), to the class for both peer and teacher evaluation using a predetermined rubric (see *Figure 2*). The course was meticulously designed to simulate the real-life scenario that these students will encounter after graduation, as they embark on their teaching careers and begin facing the challenge of finding novel and captivating approaches to engage their future students.

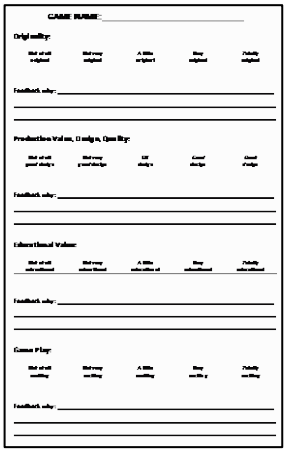

Figure 2: Evaluation Rubric

3.3 Materials Design

The **syllabus** (*Figure 3a*) was designed to guide students with no prior game knowledge, towards making informed choices regarding their own game designs whilst also considering their pedagogical implications. Weekly in-class content, including handouts, videos, games and instructions, were used in support of this goal. ***Game Evaluation Sheets*** (*Figure 3b*) were used to foster critical thinking skills regarding: 1) recognition and assessment of game mechanics, and 2) their potential use for instruction of educational content. Nearing the end of the course, ***Project Planning Sheets*** (*Figure 3c*) were distributed to students in aid of designing their final assignments by providing them with a framework for their ideas. Finally, ***Student Surveys*** (*Figure 3d*) were designed and administered to collect feedback regarding students' perceptions of games and the utilization of GBL principles for educational purposes. Samples of each handout can be seen in *Figure 3* below.

Figure 3a: Syllabus

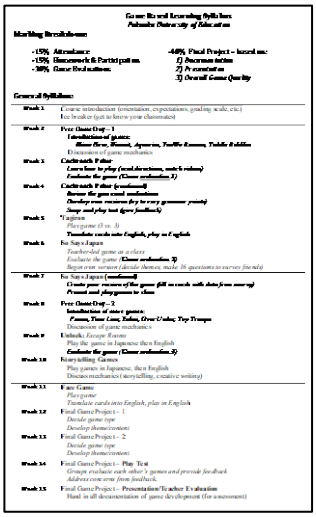

Figure 3b: Game Evaluation Sheet

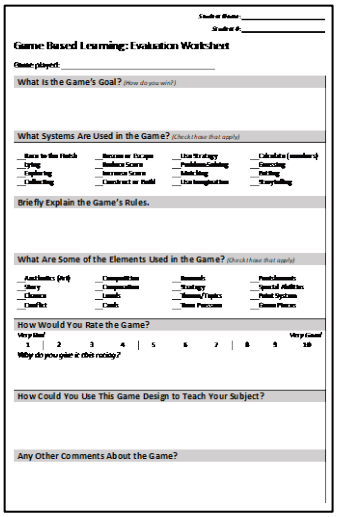

Figure 3c: Project Planning Sheet

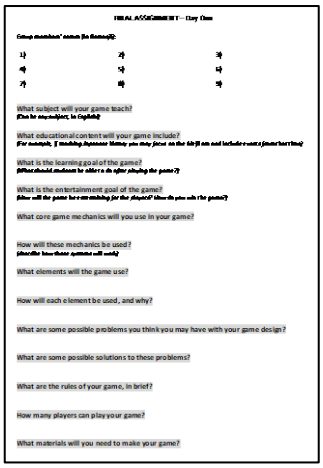

Figure 3d: Student Survey

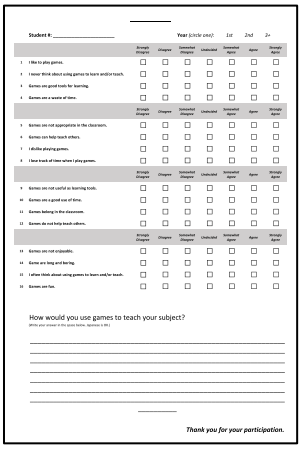

Figure 3: Materials

Overall, the materials and course content integrated into a pedagogical framework that closely adhered to Bloom's Taxonomy. Students progressed step by step through the hierarchy. Beginning at the foundational levels (remember and understand) in absorbing teacher-fronted instructions and utilizing handouts that explained various GBL and game design principles. Then transitioning to the intermediate levels (apply and analyze) by actively participating in games and subsequently evaluating them using the *Game Evaluation Sheets*. Finally, reaching the highest levels (evaluate and create) by navigating the multifaceted process of developing their own games. This approach was applied on a weekly basis within individual lessons, and carried through to their final projects.

4. Analysis

Exploratory analysis of early-stage data was undertaken in order to determine how students perceived the utility of the course's GBL content for their future teaching careers. This examination focused on 1) the students' written responses to the following question from the *Student Survey* (*Figure 3d*): "How would you use games to teach your subject?" As well as on 2) instructor feedback and 3) the quality of work produced by students for their final task-based assignment. It was anticipated that if the students genuinely believed that GBL and game design principles could positively impact their teaching careers, they would convey this sentiment within their written responses. Manifestations of this belief (or lack thereof) were thought to take one, or a combination of, the following forms:

1. **Understanding:** Students demonstrate a clear understanding of the effectiveness of GBL and game design principles, as in the following example: *"I want children to know the importance of having their own thoughts. So, I want to use creative games like Cat & Chocolate. I think this example is applicable to all subjects."*
2. **Synthesis:** Students provide practical examples or use cases to illustrate how GBL and game design principles can be effectively applied in teaching, for example: *"I want to teach social studies to my students. If I use games in social studies, I want to use quiz style games. For example, What is the color of Brazil's flag? What is the main food of Italy? What are the traditional clothes of Korea? The person who answers get points."*
3. **Articulation:** Students directly articulate their belief that GBL and game design will enhance their future careers in education, for instance: *"I want to think about games in the classroom again. At first, I didn't think that GBL for students was appropriate, but after this class, I strongly agree to using games in the classroom. I think the arrangement of games is a better teaching tool than textbooks. Remembering words, calculations, teaching skills and enforcing team play suits GBL. Thank you for teaching GBL. I will use if for education and change boring classes to interesting, exciting classes."*
4. **Negative:** Students express an obvious dislike of the course and/or its' content, give an indiscernible answer that demonstrated a lack of engagement with the course material, or there is a complete omission of response. For example: *"I don't want to use games, because playing games in class is not good or enjoyable."*

These four categories served as labels for coding students' written responses, enabling researchers to gain a more comprehensive understanding of how students perceived the usefulness of GBL and game design in their future careers in education. In addition, instructors met after weekly sessions to review their classroom observations related to student engagement levels, inadvertently comparing the new GBL curriculum to traditional methods of EFL instruction that had previously been employed. Finally, researchers also took pictures of the games students created as part of their final assignments, and used them to assess the extent to which student groups successfully applied the principles taught throughout the course.

5. Results

Table 2 depicts the overall distribution of responses based on the categories of analysis described previously. Most students were able to demonstrate in their written responses their **understanding** of the principles taught throughout the course, their ability to **synthesize** that information, and/or directly **articulate** their valuing of GBL and game design with regards to education. In nearly all cases, individual responses expressed some combination of all three characteristics, thus the discrepancy between the number of participants and coded responses. Students that found the course content to be inappropriate were few, with most **negative** responses being coded as such due to indiscernible or omitted answers. Overall, these results indicate that the vast majority of participants found GBL principles as being valuable to their future careers as educators.

Table 2: Student Responses by Category

		Understanding	Synthesis	Articulation	Negative
Spring	1st year	15	14	14	4
	2nd year	17	16	16	5
Fall	1st year	20	20	22	7
	2nd year	25	23	28	7
TOTAL		77	73	80	23

Instructor-based class observations consistently reported higher levels of student engagement compared to previously used teaching methods, both on a weekly basis and throughout the final month-long task-based assignment. Additional evidence of students' enthusiasm for Game-Based Learning (GBL) surfaced in the exceptional quality of work submitted for the final assessment. Although a few student groups opted for basic roll-and-move or quiz-type project designs, the majority exceeded teacher expectations by producing content of nearly publishable quality. Figure 4 illustrates two examples of rather sophisticated game designs.

Figure 4: Examples of Final Projects

From an EFL perspective, the course offered a substantial amount of language content, encompassing topics, vocabulary and grammar, ranging from everyday conversational items used during gameplay, to more technical aspects of grammar presented within instruction manuals, to academic level vocabulary used to explain the pedagogy underlying the course. The curriculum's task and project-based format provided opportunities for students to practice all aspects of language, including: listening, speaking, reading, and writing. Authentic interaction facilitated the vast majority of language acquisition, which was evidenced by native-like interaction during gameplay. However, one drawback to the course was its lack of accountability, as there was no way to assess the extent of students' retention of the material.

6. Discussion

Upon completion of the course, the overwhelming majority of participants expressed their understanding of GBL concepts, demonstrated their application through synthesis, and/or articulated their importance in educational settings. These findings highlight the considerable value that GBL principles hold for Japanese students of education, and therefore refute the common misconception that games do not belong in the classroom. The impact of GBL on student learning and engagement was evident through the high-quality work showcased in students' final projects as well as instructor observations. Although there were some instances of overly simplistic work, the vast majority of assignments exceeded teacher expectations, thereby indicating the potential for GBL to nurture creativity and problem-solving skills.

Furthermore, the authenticity of in-class gameplay interactions played a pivotal role in language development, increasing perceived levels of English fluency without the need for explicit instruction. The social aspects of GBL also contributed positively to student motivation and language fluency, by creating a stimulating learning environment which many of these future educators said they hope to someday recreate. While the benefits of GBL in EFL are evident, the course's drawback was the lack of a clear method for assessing long-term retention of content. To address this limitation, alternative assessment strategies, such as formative assessments and follow-up evaluations, could be considered. Additionally, educators and curriculum designers should carefully integrate GBL principles with traditional language learning methods to ensure a comprehensive and effective language acquisition process.

Moreover, the findings of this study have implications beyond the specific context of Japanese EFL students in education. Given the positive results and alignment with language learning theories, educators in various EFL contexts can adopt GBL to enhance language acquisition and student engagement. This study underscores the importance of incorporating GBL principles into teacher preparation programs to equip future educators with innovative and effective pedagogical approaches. As the field of GBL continues to evolve, further research can explore its impact in diverse educational settings and contribute to a deeper understanding of its potential benefits for language learning and beyond.

7. Conclusion

In conclusion, this research has explored the integration of game-based learning (GBL) principles into an English as a Second Language (EFL) curriculum for Japanese students of education. The study's preliminary findings suggest that GBL offers significant value for these students, both as EFL learners and future educators. This was shown through the participants' ability to express their understanding of GBL concepts and their potential application in educational settings, as well as the positive impact this curriculum had on student learning and engagement, evidenced by the high-quality final projects' students produced and instructor observations. These findings highlight GBL's unique ability to nurture creativity, problem-solving skills, and language fluency—all essential tools for educators.

Despite the study identifying a limitation in assessing long-term retention of content, the overall positive outcomes emphasize the importance of incorporating GBL and modern game design concepts into EFL classrooms and teacher preparation programs. Beyond the specific context of this study, GBL holds promising implications for EFL education globally, offering innovative and effective pedagogical approaches to meet the demands of modern classrooms. As educators continue to explore GBL's potential, further research will contribute to a deeper understanding of its benefits for language learning and beyond.

Future considerations involve enhancing the student surveys with more detailed and specific measurement items to gain deeper insights into the specific aspects of Game-Based Learning (GBL) that participants found beneficial for their future careers. Findings based on such improvements would greatly aid the claims made in the present study, which is exploratory in nature and design. Possible areas to explore in the future include student reception, impact on learning outcomes and engagement, as well as GBL's ability to foster authentic forms of interaction. To ensure reliable results, it is recommended to conduct surveys twice per semester—pre and post-intervention—to measure changes in student perceptions over time more effectively.

Regarding EFL content, future curriculums with a similar design would gain significant advantages from enhanced support for language elements. This support could include vocabulary lists, encountered grammatical patterns, useful gameplay phrases, and more. While some of these language components naturally emerge in task/project-based pedagogical approaches, identifying recurring language items and incorporating them into the course structure could potentially accelerate students' acquisition of this new language.

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Literature Review for the Design Methods of Serious Games

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Abstract: This study emphasises the primary designing characteristics of serious games that make a balance between entertainment and education. The method description was utilised as a tool based on the analysis of serious game structure, strategies, model application, and factors of games supporting entertainment and the learning process in the literature. Through Summon system (a systematic digital library that includes various popular digital libraries), 52 potential studies were collected within the recent five years (from 2018 to 2023). The result shows that 13 methods are utilised to design serious games in reviewed papers. These methods involve a diversity of design theories proposed in these papers selected and some potential dimensions that impact the design of serious games to create the balance between entertainment and education.

Keywords: Serious game, Design methods, Educational theories, Dimensions

1. Introduction

Serious games (SG) are designed as particular digital games that not only consider entertainment goals (Rosenthal and Ratan, 2022) but the most facilitate learning (Ávila-Pesántez et al., 2017). Rosenthal and Ratan (2022) indicate that SGs enable more effective promote teaching, motivating, and persuading (Jacobs, 2021) by balancing the serious and the enjoyment nature of the games. In this perspective, many studies (e.g., Czauderna and Guardiola, 2019; Hwang and Helser, 2022; Tsiotras and Xinogalos, 2021) propose various methods to create balance, including incorporating pedagogical elements into gameplay, using appropriate interface technologies, building the context on a solid foundation of knowledge, and supplying simple game mechanics that innately support the game's serious goal without having any negative impacts (Caserman et al., 2020). However, a little study presents a systematic review to conduct the primary designing methodologies that balance learning and enjoyment from SGs. In order to fix the gap, this study aims to analyse SG structure, strategies, model application and factors of games supporting entertainment and the learning process in the literature, finding potential styles of design approaches, theories and related dimensions which create a balance between gaming and learning. This contribution benefits SG designers, developers and educators, as they can integrate educational innovation to address issues that allow generating SGs to be valid (Ávila-Pesántez et al., 2017).

2. Gaming-Based Learning

A large body of research proposed that some digital games were robust tools for teaching and learning (e.g., Loparev et al., 2014; Enochsson et al., 2004; Erickson et al., 2021; Guy et al., 2005) as they can generate indirect and direct advantages in the real world. Even for those who play solely for entertainment, some digital games function better as educational approaches in an informal or formal learning environment that guides gamers to specific objectives. Learning interweaves with enjoyment in such games' design. For example, games can capture and retain players' attention via entertaining mechanisms like storytelling, interactivity, and animations (Ritterfeld and Weber, 2006; Dyck et al., 2003), while efficient learning rules guide players throughout the game's content (Gee, 2006, 2009). Further, the design of digital games affords a new learning experience. Players must be adaptive in order to find different ways to complete a goal by embracing change and using the game's resources wisely (Thomas and Brown, 2011). This adaption means players' abilities are enhanced indirectly. Research shows direct advantages when using digital games in formal learning environments. For instance, such games (i.e., *Civilisation* and the *Sims*) have been combined with conventional classroom exercises to teach students about the evolution of society and its history (Young et al., 2006; McCall, 2016; Squire and Jenkins, 2003).

New designs are emerging with a developmental strategy that aids education, thanks to the successful expansion of digital games. Such 'SGs' are created by integrating educational content within the gameplay (Rosenthal and Ratan, 2022) to be different from entertainment-oriented games with learning-related. SGs have been used as an essential asset in education gradually over decades. Scholars use SGs by involving players in meaning-driven activities and creating scenarios that reflect real-world situations to encourage the formation of transportable knowledge, abilities, and mindsets (Fabricatore et al., 2019). According to Bressler et al. (2021), playing mobile augmented reality games can be beneficial for encouraging serious science learning. Although these studies mentioned SG development and design, many studies have only considered

providing general recommendations related to pedagogical elements (Cano et al., 2016). For the recommendations, there is a limitation in guiding the SG design process (Barbosa et al., 2014), leading to difficulties in generating high-quality educational games (Yusof and Rias,2014). According to Caserman et al. (2020), it is more likely to design useful SGs by balancing the game's serious and playful nature. Hence, this literature review expects to conclude these specific designing characteristics of SGs comprehensively, potential styles of design approaches and theories which create a balance between learning and enjoyment. Because some games have achieved an appropriate serious-game balance to facilitate enjoyment in learning (Rosenthal and Ratan, 2022). For example, Abdul and Felicia (2015) offered a set of guidelines for the conception of learning through play. They integrated game features and elements with a didactic method that benefits the phases established to create an adequate SG (Ávila-Pesántez et al., 2017).

3. Research Questions

The primary design characteristics of games support the development of SGs, which include game theories, game-based learning purposes and functions (Ávila-Pesántez et al., 2017). So, in this context, research questions are carried out, which focus on the aspects considered in the design methodologies. The following explanations clarify some terms in order to avoid ambiguity:

(a). The methodology is about to approach, model, framework, strategies and phases for the design of SGs (Ávila-Pesántez et al., 2017).

(b). The educational theories consider the pedagogical practice of promoting learning (Loughran, 2006) and guide the development of games.

(c). Dimensions related to elements, factors, or features that trigger action and enable an outcome (Zheng et al., 2016).

Based on the explanations of these terms, this research utilises a literature review to concern design methodologies for SGs, involving educational aspects, theories of making games and factors. For this purpose, more precisely, the following concerns are covered in this study:

RQ1. What building methodologies are utilised to create SGs?

RQ2. What educational theories impact a balance between entertainment and education for the design of SGs?

RQ3. What dimensions are used in SGs?

4. Methodology

A systematic digital library *Summon 2.0,* which includes various popular digital libraries (e.g., PsycInFO, Scopus, PubMed and Web of Science), was utilised to collect papers published in the education discipline. The initial selection (433 papers) was from journals and conference proceedings in English between January 2018 and March 2023. The search strategy was carried out based on: ((SG OR educational game OR game-based on learning) AND (design OR methodology OR strategy OR frameworks OR model)). A general review of the title and abstract was implemented to refine the initial selection to get 147 articles. The following rubrics of exclusion were applied to obtain the final selection (52 papers). See Figure 1.

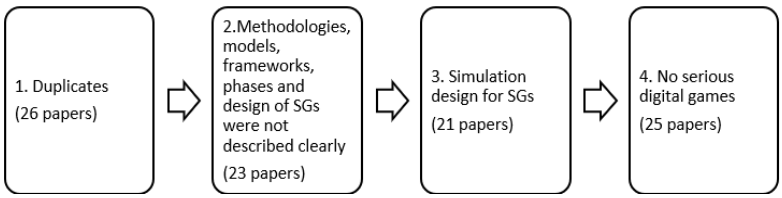

Figure 1: Selection rubrics

5. Result

The findings are shown according to the three RQs, answering the determining methodologies, educational theories, and dimensions for SG design. The related articles are listed as evidence in Figure 2.

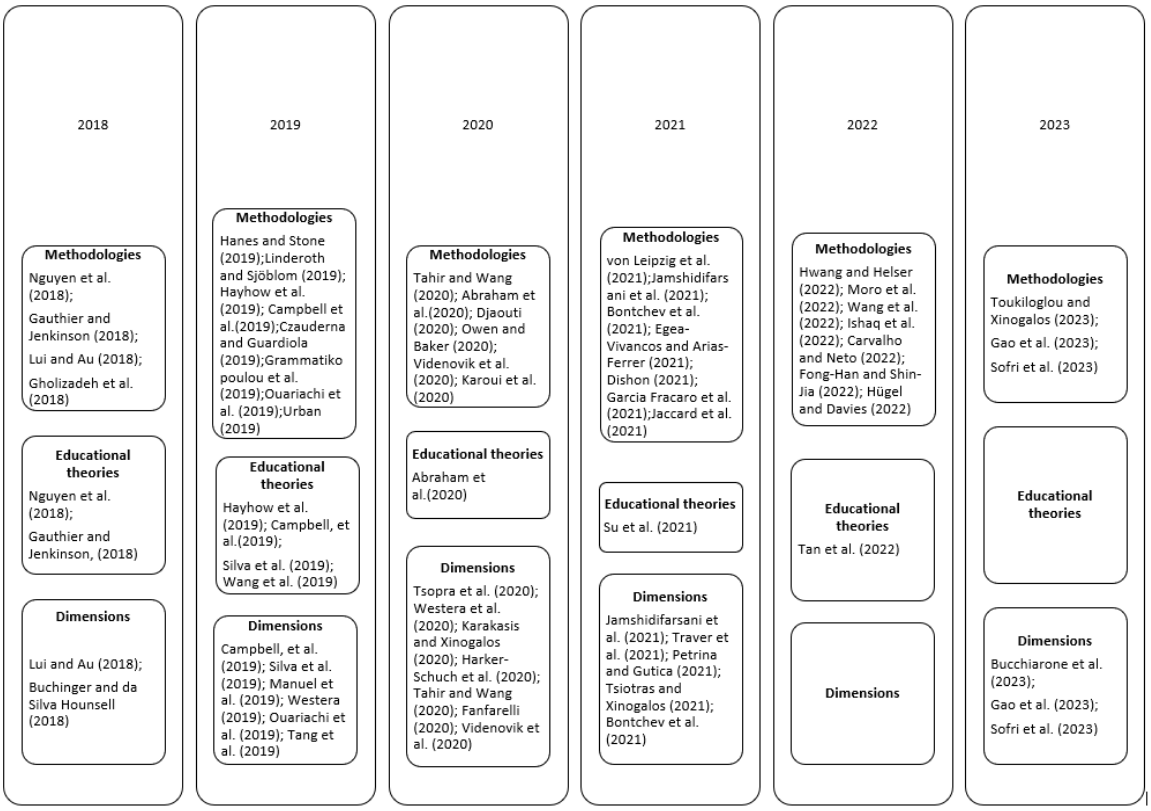

Figure 2: The details about these papers selected

RQ1. What building methodologies are utilised to create SGs?

Thirteen types of methodologies have been utilised to design SGs in 52 papers reviewed. Twenty-seven of these principles (52%) validate their proposals using experimentation processes/case studies. Five approaches (M9-M13) are used only once to design games. These guidelines enable programmers to construct an adaptable and easy-to-use system, which is consistent with Ávila-Pesántez et al. (2017). Most approaches (nine methods) consider specific pedagogical aspects from perspectives of diversity, such as educational goals, learning outcomes and game experience. See Figure 3.

Figure 3: The methodologies used to build SG

RQ2. What educational theories impact a balance between entertainment and education for the design of SGs?

Educational theories are robust underpinnings to support the development of SGs (Jayakanthan, 2002; Pourabdollahian et al., 2012). In order to answer the RQ2, six general educational theories were identified to guide the design of the serious side. The theories explored in these analysed articles included two aspects: didactic strategies (seven papers) and learning principles (four papers), aiming to enhance the learning mechanics, improving abilities and developing player's skills (Figure 4). The two aspects both support the construction of the serious side of SGs. The didactic strategies refer to the way of problem contextualization, and it outlines the goals to be met with the game's design in a situation that accommodates the requirements of the students (Cano et al., 2016). While there are conceptual frameworks for learning that explain and forecast how people learn (Schunk, 1996).

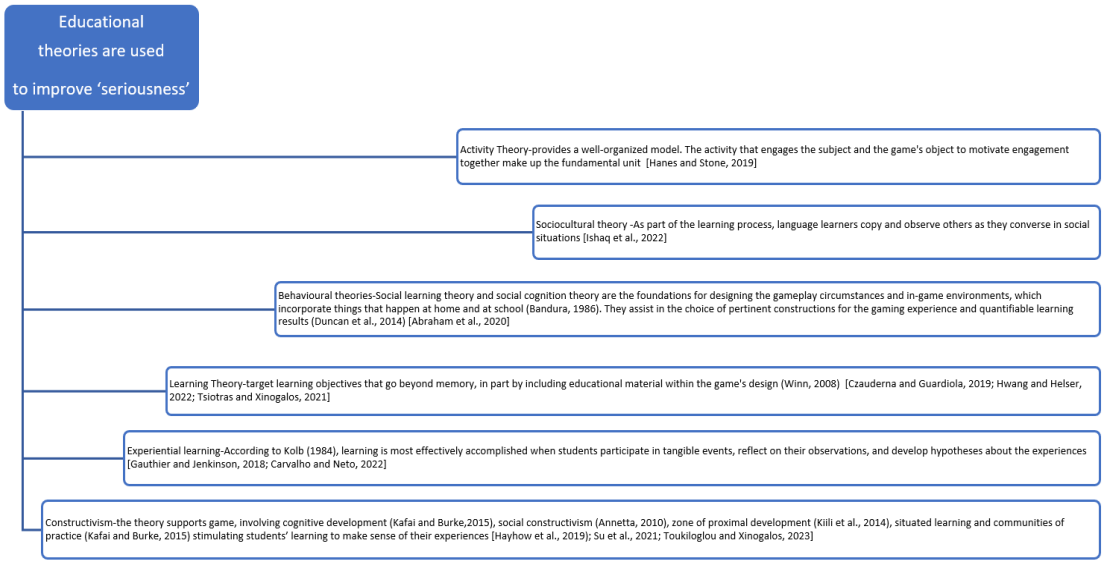

Figure 4: Educational theories used to improve 'seriousness'

Several theories were proposed in selected articles to support the fun of SGs, where students reported much better levels of fun and learnt significantly more than those who learned through traditional means (Fanfarelli, 2020). See Figure 5.

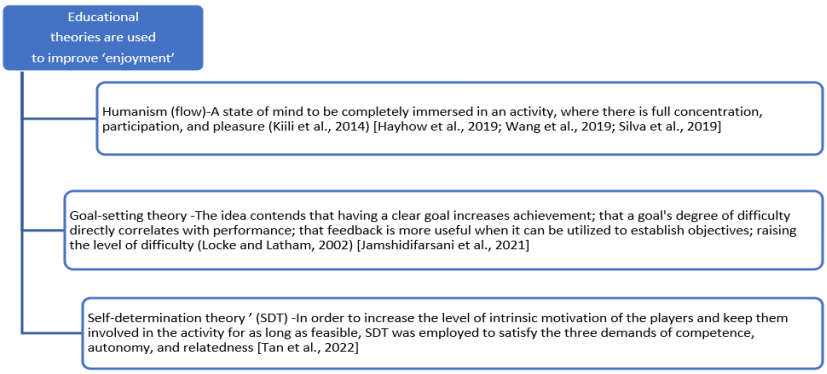

Figure 5: Educational theories used to improve 'enjoyment'

RQ3. What dimensions are used in SGs?

The authors identified 41 dimensions related to the design of SGs (Table 1, 2), which are classified regarding general game features (10 dimensions) (e.g., game story) and development factors (31 dimensions) (e.g., AI). The finding demonstrates that some common traits help create different games (aesthetics care) (Takaoka et al., 2012), and because development methodologies are mentioned in RQ1, some critical factors were extracted from them.

Such elements including the game story, characters, tasks and scenes were frequently mentioned in the general game features analysed. These features can create a relationship of participation among players, so

they are utilised to keep the duration of the game's actions (Ávila-Pesántez et al., 2017). For the development factors, it is visualized that game achievement and dilemma are the most cited in the documents reviewed. If players can complete one of them (i.e., game achievement and dilemma) that is likely to be proved players' abilities, creating a feeling of growth and progress (Ávila-Pesántez et al., 2017).

Table 1: The general game features used in SGs

General game features	References
Game endings	(Gao et al., 2023)
Game tasks/ content design/ Learning activity/ Game goals	(Gao et al., 2023); (Petrina and Gutica, 2021); (Tsiotras and Xinogalos, 2021); (Tahir and Wang, 2020)
Game story/Motivating Storyline/ narrative	(Gao et al., 2023); (Tang et al., 2019); (Fanfarelli, 2020); (Petrina and Gutica, 2021); (Tahir and Wang, 2020)
Game avatar/ Characters/ Avatar with badges/Identity	(Gao et al., 2023); (Manuel et al., 2019); (Tsopra et al., 2020); (Harker-Schuch et al., 2020); (Petrina and Gutica, 2021); (Tahir and Wang, 2020); (Jamshidifarsani et al., 2021)
Game tools/Items/ Game resources	(Gao et al., 2023); (Manuel et al., 2019); (Tahir and Wang, 2020)
Game mode	(Gao et al., 2023)
Non-plater character (NPC)	(Petrina and Gutica, 2021); (Gao et al. 2023);
Hidden Messages and Side Jokes/ Hints/Help	(Tang et al., 2019); (Tsopra et al., 2020); (Jamshidifarsani et al., 2021)
Cutscenes (can introduce linear non-interactive narrative sequences)	(Manuel et al., 2019);
Scenes/Style elements (includes rich audio-scopes and engaging visuals)/ The game design of a particular style (special sound or scenarios)/ variety of activities	(Manuel et al., 2019); (Westera, 2019); (Gao et al. 2023); (Karakasis and Xinogalos, 2020)

Table 2: The development factors used in SGs

Development factors	References
Level/ Progress bar/ Levels of difficulty, metaphors and semiotics	(Bucchiarone et al., 2023); (Tsopra et al., 2020); (Petrina and Gutica, 2021)
Progression	(Bucchiarone et al., 2023)
Point/Reward systems/scores/Achievement	(Bucchiarone et al., 2023); (Westera, 2019); (Tsopra et al., 2020); (Karakasis and Xinogalos, 2020); (Tsiotras and Xinogalos, 2021); (Jamshidifarsani et al., 2021)
Leader board	(Tsopra et al., 2020)
Scaffolding (instruction in text format)	(Karakasis and Xinogalos, 2020)
repeatability (a player masters a task by repeating a set of actions)	(Petrina and Gutica, 2021)
Gameplay	(Tahir and Wang, 2020)
Artificial intelligence (AI) (including personalisation, difficulty balancing, evaluation, player analytics, competence modelling, social gamification, technical considerations and affective computing)/ Technical	(Westera et al., 2020); (Tahir and Wang, 2020)
Dilemma/Challenge provided/Increasing complexity/ Game play	(Tang et al., 2019); (Silva et al., 2019); (Tsopra et al., 2020); (Harker-Schuch et al., 2020); (Lui and Au,

Development factors	References
	2018); (Tahir and Wang, 2020); (Jamshidifarsani et al., 2021)
Real-Life Scenarios	(Tang et al., 2019)
Concentration (enable players to be fully absorbed in their tasks)/ Immersion in the real world/ Flow	(Silva et al., 2019); (Tsopra et al., 2020); (Harker-Schuch et al., 2020); (Lui and Au, 2018); (Tahir and Wang, 2020)
Clarity Goals/Intended learning outcomes/ Learning objective	(Silva et al., 2019); (Tsiotras and Xinogalos, 2021); (Tahir and Wang, 2020); (Jamshidifarsani et al., 2021)
Give players feedback/ informed teaching/ Reflection	(Silva et al., 2019); (Tsopra et al., 2020); (Harker-Schuch et al., 2020); (Tsiotras and Xinogalos, 2021); (Jamshidifarsani et al., 2021)
Autonomy to the user (make the players feel in charge of their own actions and performance)	(Silva et al., 2019); (Lui and Au, 2018)
Social Interaction/ Interactivity/Interface	(Silva et al., 2019); (Harker-Schuch et al., 2020); (Lui and Au, 2018); (Tahir and Wang, 2020); (Jamshidifarsani et al., 2021)
Perceived learning (players can do what they need and want)/ The instructional element (the players can play that follows their own pace)/Game attributes/ control/ Learnability	(Silva et al., 2019); (Harker-Schuch et al., 2020); (Tsiotras and Xinogalos, 2021); (Lui and Au, 2018); (Tahir and Wang, 2020)
Gameplay scenarios (give players a way to make sense of the search for causality, space, and time relationships, which helps with game story development)	(Westera, 2019); (Tsiotras and Xinogalos, 2021)
Capability (The games are generated in a way that the players can remember basic knowledge regarding the level that they played)	(Tsiotras and Xinogalos, 2021)
Instructional content (the players learn about different concepts at per level)/ learning content	(Tsiotras and Xinogalos, 2021); (Tahir and Wang, 2020)
Game genre	(Tsiotras and Xinogalos, 2021)
Engagement	(Lui and Au, 2018); (Tahir and Wang, 2020)
Curiosity/Motivations	(Lui and Au, 2018); (Tahir and Wang, 2020)
Fantasy/ Enjoyment	(Lui and Au, 2018); (Tahir and Wang, 2020)
Competition	(Lui and Au, 2018)
Randomness	(Lui and Au, 2018)
Balance	(Lui and Au, 2018)
Learning strategies	(Tahir and Wang, 2020)
Context (the game background where game-based learning will take place)	(Tahir and Wang, 2020)
Game aesthetics	(Tahir and Wang, 2020)
Satisfaction	(Tahir and Wang, 2020)
Cognitive development	(Tahir and Wang, 2020)
Psychology needs	(Tahir and Wang, 2020)

6. Discussion and Conclusion

Based on research questions, the findings showed that the excellent design of SGs trends to new representations and interaction (Ávila-Pesántez et al., 2017) in an educational environment. In order to make a balance between serious and playful, many new approaches were proposed (e.g., M9-M13) to be utilised as a learning aid in several fields of expertise (Susi et al., 2007). Several educational theories were utilised to

highlight the entertainment aspect in order to develop learning competencies while allowing the achievement of skills based on the games. Because players can learn from their mistakes, many studies reviewed present the challenges that strengthen teamwork, collaboration, decision-making competence, and leadership (Cruz-Lara et al., 2013). The established challenges depend on the player's capability and constant feedback. These two dimensions are both reported as important aspects of development factors. Five studies attest that games aligned with learning objectives are the key component of designing SGs. The capability development of players achieved through the SG replies to the clarity of the learning objective, which is likely to promote game tasks, levels, and feedback. Furthermore, when designing SG, perceived learning was taken into account because it allows gamers to decide for themselves using their academic knowledge. The procedure ought to be examined during game creation and integrated with each activity that players undertake to provide feedback.

All in all, this literature review assists in identifying research gaps in methodologies, pedagogical theories and factors that influence the design of SGs. The contributions of this study provide helpful recommendations for creating high-quality SG because it incorporated game dimensions in promoting engagement and supporting learning.

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Game Design as Reflective Pedagogy in Entrepreneurship Education

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Abstract: The relationship between business education and games, primarily simulation games, dates to the 1930s in Europe and the 1950s in the US and continues to grow today. These games are often used to teach action-oriented disciplines, such as marketing, strategy, and entrepreneurship, providing situations in which decision-making under risky circumstances can be practiced. Our research shifts the focus from playing games to designing them for learning. Our game design activity brings the ambiguity and uncertainty from the entrepreneurial environment into the classroom, where risks can be taken, and failure is part of the experience. Students dive into an iterative design process grounded in inquiries and investigations. This requires communication and negotiation skills, aiming to construct dynamic business representations in constant conversation with the situation. Although students' lack of professional experience and game design knowledge poses challenges, the design activity uncovers many learning possibilities and discoveries. Our pedagogical approach attempts to embrace constructionists' learning characteristics by using a board game to mediate the design process, besides the gameplay. Students' designs should not only reflect their problem-solving experiences, identities, and understandings, but also construct meaning through conceptualizing business interpretations as game elements, mechanics, and rules. Through observations in university classroom settings (Canada, France, and Brazil), we present examples of students' game designs and how they interpreted entrepreneurial challenges through their designs. By employing design thinking to create conceptual representations in a meaningful game, they showed their understanding of entrepreneurship, worldviews, and contextual knowledge grounded in their sociocultural contexts. A board game became a tool that embodied design possibilities based on low-cost resources and was used in classrooms without computers, internet access, or other technical devices. A board game provides an inclusive and immersive learning experience that supports better conceptual understandings of systems, such as entrepreneurial activity. This research contributes not only to understanding the role of board games in business education (in contrast with prevalent digital simulation games) but also motivates the next generation of entrepreneurial educators to experiment with novel teaching methods.

Keywords: Game design, Game-based learning, Entrepreneurship education, Design thinking

1. Introduction

The field of entrepreneurship education is continuously seeking innovative pedagogical approaches that promote experiential learning and engage students in meaningful ways. Experiential learning aspires to bridge the divide between theoretical knowledge and practical application by incorporating problem-based learning (Tan and Ng, 2012), student-initiated business ventures, real-world case studies, and simulation games (Kassean *et al.*, 2015) into the classroom.

A simulation game can be classified as a distinct genre within the broader scope of games, characterized by its aim to replicate real-world processes, systems, or scenarios, enabling players to engage with and manipulate these simulated elements (Sauvé, Renaud and Kaufman, 2010). The fundamental objective of a simulation game, for some authors also refers as a serious game (Fox, Pittaway and Uzuegbunam, 2018), is to provide an immersive and interactive learning experience that fosters a comprehensive understanding, exploration, and acquisition of knowledge on various facets of the simulated system or situation. Inherent to simulation games are elements of decision-making, strategy formulation, and problem-solving, as players assume the role of active agents within the simulated environment, necessitating thoughtful choices and the discernment of consequences arising from their actions. It is noteworthy to mention that within the context of this study, the term "games" specifically alludes to simulation games, underscoring their distinctive nature and purpose in the analysis and exploration conducted herein.

Despite its potential benefits, the utilization of game design as an experiential approach remains underexplored within entrepreneurship education. Nevertheless, game design presents a distinctive opportunity for students to examine entrepreneurship concepts and cultivate essential skills. This study probes the challenges and prospects of incorporating game design activities in entrepreneurship education, with a focus on understanding how students, especially those lacking professional experience or game design expertise, navigate the process of designing games.

By examining various game designs, this paper investigates the initial game design concepts, the impact of students' backgrounds, experiences, and pre-existing game knowledge, as well as the iterative process that culminates in more sophisticated and meaningful game designs. Additionally, the paper analyses the interrelated

components that undergird students' approaches to game design, emphasizing the significance of socio-cultural contexts and interdisciplinary knowledge in shaping their educational games.

This paper, situated within a constructionist framework (Papert, 1991; Kafai, 2006), seeks to enhance our understanding of game design as an educational approach for entrepreneurship education. By doing so, we provide valuable perspectives on the difficulties faced by students, the educational possibilities that arise from engaging in game design, and recommendations for effectively implementing this activity to enhance students' design competencies.

2. Game Design as a Pedagogy

Within educational contexts, games are purposefully designed to generate immersive experiences. Players learn to draw inferences about the game's elements and negotiate their meanings within real-world social and cultural contexts (DeVane, Durga and Squire, 2010). Consequently, games serve as a metaphorical medium for experimenting with and enacting radical changes, testing ideas in a safe environment, and providing players with a context for interpretation. Games are distinct from other media in that they offer players the opportunity to influence outcomes through their own efforts (Isbister, 2016).

Business education and games share a long-standing relationship. Their interconnected history dates back to the 1930s in Europe and the 1950s in the United States (Faria *et al.*, 2009), with the continuous evolution of business gaming resulting from advancements in war games, operations research, computer technology, and educational theory (Wolfe, 1993). In this context, game design as a pedagogical approach pertains to the design and/or programming of games (digital games), supporting learning objectives such as coding concepts, design literacy or design thinking, critical thinking, systems thinking, and problem-solving (Kim and Bastani, 2017; Martins and Oliveira, 2018).

One learning theory that underpins game design as a pedagogical activity is constructionism, first proposed by Seymour Papert (Papert, 1991). Constructionism is rooted in constructivism (Holmes and Gee, 2016), which perceives learning as an active process wherein learners construct new ideas or concepts based on their existing and prior knowledge, social interactions, and motivation. Constructionism extends these elements by proposing that the process necessitates a tangible artifact as an outcome that can be shared with others (Kafai and Burke, 2015; Holmes and Gee, 2016). In this regard, instead of embedding lessons within games, constructionism advocates for students to construct their own games as artifacts, forging new relationships with knowledge during the design process (Kafai, 2006). Under this perspective, games are conceptualized as objects-to-think-with (Papert, 1980), providing an engaging medium for students to introspectively examine and integrate their old and new insights about entrepreneurship. Furthermore, a pedagogy grounded in game design fosters more inclusive learning environments capable of engaging students with diverse skills by exploring their interests and creativity during the design process (Kim and Bastani, 2017).

Several studies have reported successes in implementing game design as a tool in teaching and learning practices. Hwang, Hung, and Chen (2014) conducted a study on an elementary school science course, wherein a digital design game activity promoted problem-solving skills. Yang and Chang (2013) demonstrated that digital game design in a biology course for two seventh-grade classes enhanced students' critical thinking skills. In higher education, Marasco et al. (2017) reported that engineering students developed creative, problem-solving, time, and project management skills by designing games in a technical course. Gaskin and Berente (2011) asserted that a digital game design workshop could enhance design thinking among Master of Business Administration (MBA) students.

However, board games provide more cost-effective opportunities for design and represent an actual social practice, not only during the design activity but also throughout gameplay sessions. Despite this, only a few initiatives in the literature report the use of board game design in classroom settings. Most of these initiatives involve teachers adapting or modifying commercial games or custom-built games for use in their courses (Castronova and Knowles, 2015; Sánchez *et al.*, 2017; Hoy, 2018). Kim and Bastani (2017) discussed board game design as an educational intervention, showcasing a study in which eighth-grade students designed their own board and card games, integrating various disciplines to incorporate multiple sources of knowledge in science, technology, engineering, art, and math (STEAM) education.

Business instructors employ games as a pedagogical tool to offer students diverse and immersive entrepreneurial business experiences (Pittaway and Cope, 2007), facilitating learning and enhancing students' skills. Fox et al. (2018) argued that games enable players to learn in various ways, such as through doing,

reflecting, and experiencing failure. Students perceive gameplay as a valuable educational exercise that expands their knowledge of entrepreneurial decision variables (Fox, Pittaway and Uzuegbunam, 2018).

While gameplay focuses on problem-solving and decision-making within a controlled environment governed by game rules, game design offers students, as game designers, opportunities to exercise their storytelling, design thinking, and creative thinking skills. A game design activity generates contextualized and authentic learning experiences, making knowledge and skills acquired through project-like work more transferable to future situations (Ke, 2014).

Furthermore, business students typically do not receive hands-on training related to new product development, as found in design education (Christensen *et al.*, 2022). Introducing game design to entrepreneurship classes will not only develop students' problem-solving skills but also provide reflective training in material interaction, enabling students to create tangible representations of their conceptual understandings. This process should assist students in articulating and continually questioning their mental frameworks concerning entrepreneurship.

3. The Challenges and Opportunities in Game Design

The game design activity seeks to introduce the ambiguity and uncertainty inherent in the entrepreneurial environment into the classroom, creating a space where risks can be taken, failure is enjoyable, and taboos can be challenged. The designer perspective inherent in this activity necessitates a transition from teacher-driven knowledge transmission to a conception of knowledge as a dynamic construct driven by students.

However, our research indicates that students need support to navigate this design process. The initial prototype typically reflects rudimentary and simplistic perspectives of the entrepreneurial activity, manifesting in a game design with basic mechanics, game elements, and rules. The method for implementing this design activity is as follows: after the first prototype, students pitch ideas (as products), followed by a feedback session, an instructor-supported iterative design process to refine ideas, and a playtest session. During the playtest session, students play each other's games and provide written feedback. Subsequently, a debriefing session is held, followed by an individual written report in which students describe their experiences playing and designing the game and the lessons learned from this process. To conclude the report, students present an analysis of the lessons learned and their connection to other courses in the program.

While students' lack of professional experience and game design knowledge presents challenges to this activity, numerous learning opportunities and discoveries also emerge. The challenge lies in guiding students, as non-designers, to engage in an iterative design process rooted in inquiries and investigations, necessitating communication and negotiation skills as they work in groups and aim to construct business representations (Visser, 2006) through constant dialogue with the situation (Schön, 1983). Learning opportunities are embedded in the process of participating, engaging, and/or interacting with and around the game (Bayeck, 2020). The overarching goal of the game design activity is not to produce a ready-to-market game; rather, students' designs should reflect not only their problem-solving experiences, identities, and understandings, but also construct meaning (Krippendorff, 2006) through conceptual business interpretations articulated as game elements, mechanics, and rules.

4. Research Design

This study employed a design-based research (DBR) approach to investigate the potential of game design as a teaching method in entrepreneurship education. DBR was originally developed in the 1990s (Brown, 1992; Collins, 1992) to address various issues in the realm of education. These issues included theoretical inquiries about the nature of learning in specific contexts, the necessity to move beyond limited measures of learning, the need to derive research outcomes from formative evaluation, and the examination of learning phenomena in authentic settings rather than controlled laboratory environments (Collins, Joseph and Bielaczyc, 2004).

DBR can be defined as a "series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab and Squire, 2004, p. 2). By conducting research in authentic contexts, DBR enhances the validity of the findings and suggests that the results could have significance not only within the context of the intervention but also in other similar contexts (Anderson and Shattuck, 2012). DBR primarily focuses on developing and refining innovative educational designs, interventions, or technological solutions, aiming to create and test new educational theories, practices, or tools in real learning environments.

Numerous frameworks have been proposed for design research, such as those suggested by Bannan-Ritland and Baek (2008), Easterday et al. (2014), Edelson (2002), and Kennedy-Clark (2013). For this study, we drew inspiration from McKenney and Reeves's (2012) framework, which encompasses a series of iterative cycles representing the interaction between the design and the context, leading to an improved design and understanding of the intervention. Our initial step involved various formats, such as reflections, research group discussions, previous experiences, and literature reviews, to shape a game design experience suitable for implementation in the classroom. The subsequent step entailed conceiving a game design activity to address the problems and diagnoses that emerged during the previous stage. Finally, we conducted prototype tests (reported in this paper) wherein qualitative data were collected through observations and artifact examinations.

Observations were conducted in a non-intrusive manner, allowing students to engage in the game design process naturally. The first author took detailed field notes, focusing on students' interactions, collaboration, problem-solving, decision-making, and the evolution of their game designs. Additionally, the first author documented the students' game concepts, prototypes, and final game designs.

The researchers systematically analyzed the field notes, game concepts, prototypes, and final game designs. The analysis focused on identifying common elements and patterns in students' approaches to game design, the integration of entrepreneurship concepts, and the development of skills and competencies throughout the process. Thematic analysis was employed to categorize the data and identify prevalent themes related to the research questions.

The results presented in this work could be considered a work-in-progress, as DBR typically follows an iterative design and evaluation process. This process involves developing a design or intervention, implementing it in real-world settings, collecting data on its effectiveness, and iteratively refining the design based on the findings.

5. Game Design in Action

5.1 Designing Games for Knowledge Representation

When students are initially challenged to design a game that represents their knowledge about a given discipline, the first ideas that emerge often resemble trivia-style games. Some variations also appear, such as games where players move along a path on the board and must answer a question upon landing on specific spots.

An example of this is a game designed by a group of students in France, titled "Who Will Be the Best Entrepreneur of the Year?" (Figure 1). The initial design was a traditional quiz game featuring questions based on course content. After receiving feedback, the students refined their idea to present a game in which players analyze business opportunities across four domains (human resources and accounting, research and development, product and pricing, and communication and marketing) as they progress around the board. The colors of the squares indicate the type of card and corresponding opportunity to be assessed.

Figure 1: Who will be the best entrepreneur of the year?

Another project that began as a quiz game was "Tackle" (Figure 2). Led by two American female students, this project underwent significant revisions after the feedback session, resulting in a more engaging game. In Tackle, the students employed an unbalanced design in which players assume the roles of different characters aspiring

to be entrepreneurs. Each character has a unique background, starting the game at different positions on the board and with varying amounts of money according to their profile. The students crafted this design to explore societal inequalities and their consequences for entrepreneurship. For instance, playing as a white male entrepreneur provides the player with a shorter path to success and a more comfortable initial investment for starting a business. In contrast, if a player assumes the role of a black woman, they encounter greater difficulties and constraints in reaching the same position.

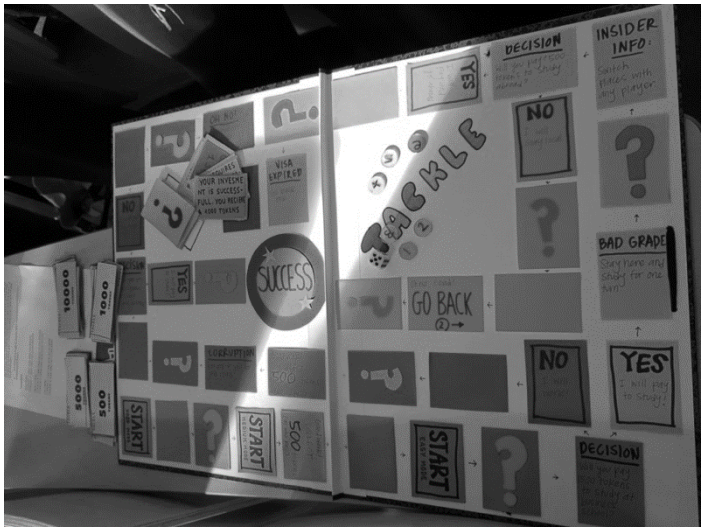

Figure 2: Tackle

5.2 Drawing on their prior experiences, and socio-cultural backgrounds

When students brainstorm game designs, quiz-style games are often the first ideas that emerge, and the students' backgrounds tend to be the primary components they incorporate into their games. For instance, students from a Brazilian college created a game called "Empreenda Aí" (roughly translated to "Go for It"), which reflects the struggles of being an entrepreneur in their country, particularly the difficulties in navigating complex tax legislation. The main board depicts São Paulo, one of Brazil's most industrialized states, where cities are interconnected by roads. Players must purchase raw materials, produce goods in their factories (represented on the players' boards), and sell their products in the cities on the main board. As companies expand, players must pay taxes based on varying percentages according to company size. Additionally, freight costs between cities must be paid.

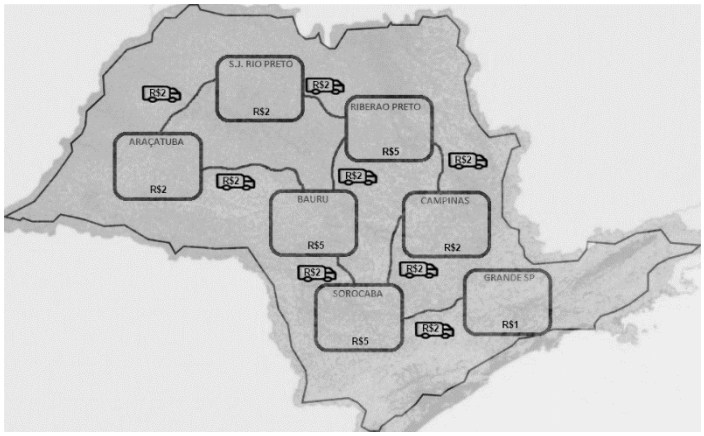

Figure 3: Empreenda aí

Students' backgrounds encompass not only their personal experiences and observations, but also the types of board games they have played, which can significantly influence their designs. A prime example of such influence is the game Monopoly (Darrow and Magie, 1935), which has served as a key reference for many students. French students' games, "Strat' Game" and "Competitive Business," are examples of modified versions of Monopoly (Darrow and Magie, 1935) that introduce strategy concepts related to entrepreneurial activities. As players

progress around the board, they answer questions pertaining to the course, with the ultimate goal of accumulating as much money as possible.

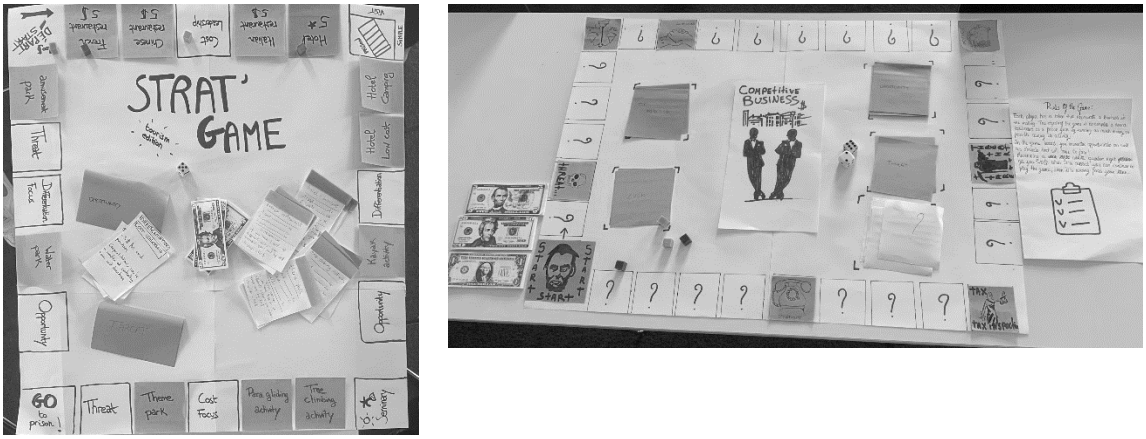

Figure 4: Strat' Game and Competitive Business

5.3 Thinking With Existing Games

While students learn through the adaptation of traditional board games, more sophisticated designs involve more than simply modifying elements to represent entrepreneurship constructs. Rather, effective designs necessitate in-depth reflection to facilitate the integration of course content, novel elements, and diverse game mechanics into the original design. Though the original game design may still be discernible in the students' final work, the new game creatively explores the main disciplinary ideas. For example, in order to represent their knowledge of various supply chain topics, students at a Canadian college modified the traditional "The Game of Life" (Klamer and Markham, 1960) to create "The Game of Supply Chain" (Figure 5). In this game, players perform different actions on the main board as well as on an individual board representing their factories (Production Cycle). As players establish a company, produce goods in their factories, and sell products, they encounter and address situations presented by action cards (e.g., raw material shortages) as they move around the board. The game demands strategic thinking from players while teaching supply chain management concepts embedded in entrepreneurship.

Figure 5: The Game of Supply Chain

"The Game of Life" (Klamer and Markham, 1960) also served as the foundation for another game design in Canada. "The Life of an Entrepreneur" (Figure 6) is a game that portrays the innovative journey of an entrepreneur, highlighting the numerous difficult choices they must make to maintain a successful business. Players, as unique characters, encounter real-life decisions and accumulate assets and liabilities throughout the game. Additionally, the game introduces risky and unethical paths, prompting players to reflect on these issues in the context of entrepreneurship.

Figure 6: The life of an entrepreneur

Another example from a university in Canada combines elements and game mechanics from Risk (Lamorisse and Levin, 1959), Catan (Teuber, 1995), and Pandemic (Leacock, 2008) to create "Footprint Factor" (Figure 7). This project began with the premise that continuous economic growth and environmental conservation are incompatible. The game reproduces this reasoning by inviting players to experience the logic of sustainable development. "Footprint Factor" challenges players to navigate a complex and interconnected system while promoting sustainable practices in business operations and addressing the environmental impact of entrepreneurial activities. Players must collect resources from the planet (lumber, water, minerals, and oil) and combine them to open factories, produce, and sell products. As they sell, they cause negative impacts on the environment. However, their money can be used to purchase various resources (technology, researchers, and clean energy) to upgrade their factories, transforming them into environmentally friendly operations.

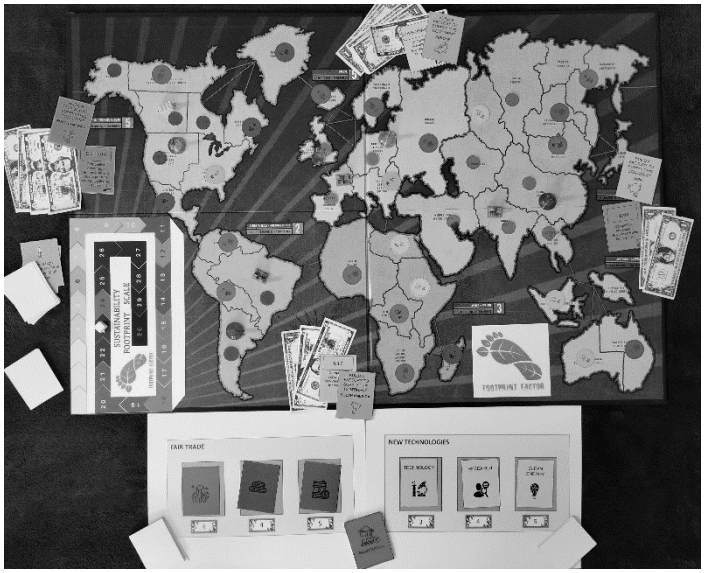

Figure 7: Footprint factor

5.4 Critical Thinking for Entrepreneurship Complexity

"Conquer the Market: An Entrepreneurship Game" (Figure 8) is a sophisticated example of how a game modification can result in an intricate design. Developed by French entrepreneurship students, inspired by the game Catan (Teuber, 1995), the game challenges players to gather tangible and intangible resources that are identified as gaps in the market, ideas, knowledge, network (human capital), and money. By combining these resources, players can build elements such as factories, warehouses, retail stores, and supply chains that must be connected to each other. The game also features cards with both positive and negative impacts on players. The winner is the player who builds a factory, a warehouse, and a retail store in the correct order, connected by

the supply chain, and reaching the customers located on the edge of the board. This project introduced a new design challenge since it was created using the Tabletopia (*Tabletopia*, 2014) website. The students studied how to design the game components on the website, which allowed them to develop knowledge not only related to entrepreneurship concepts, such as the venture creation process and product production and distribution, but also in computation and graphic design.

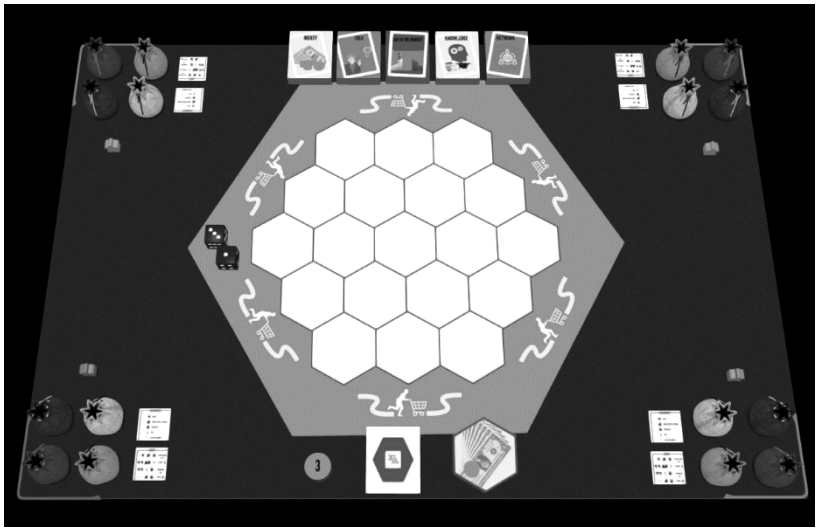

Figure 8: Conquer the market: An entrepreneurship game

The game design activity is not confined to board games, as card games also offer promising opportunities for students to express their creativity while forging meaningful connections with entrepreneurship concepts. Entrepreneurial Prestige (Figure 9) is an example of a card game built upon the Dominion (Vaccarino, 2008) game. The game's objective is to use various cards based on the business model canvas to develop a personalized business strategy and gain prestige. The three types of prestige are brand awareness (the lowest), brand reputation (middle), and brand recognition (the largest). The action cards enable players to diversify their strategy by utilizing skills to purchase more cards, obtain additional funding, and develop more prestige. The funding cards provide players with the currency required to purchase other cards. There are three main funding cards: Friends and Family, Venture Capital, and Investors. Finally, the Prestige cards count towards Business Prestige points at the end of the game.

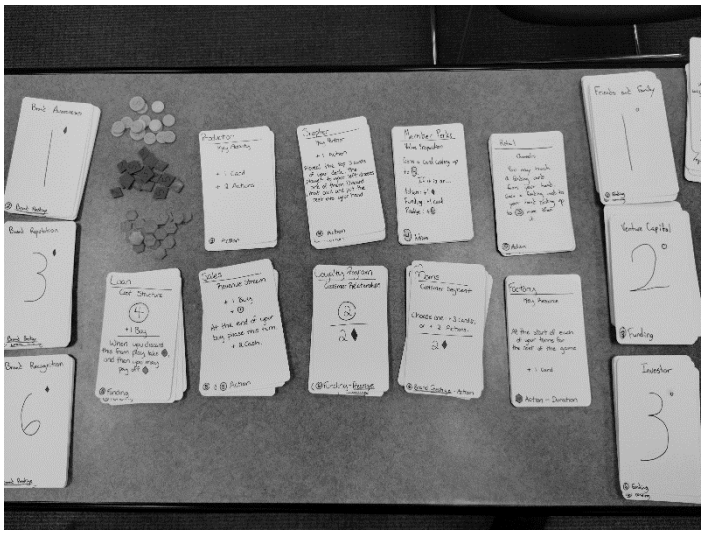

Figure 9: Entrepreneurial Prestige

6. Conclusions

Upon examining the games created by students in the context of entrepreneurship education, several common elements emerge that contribute to the development of essential skills and competencies. These shared

experiences and approaches highlight the potential of game design as a pedagogical tool that encourages creativity, collaboration, and experiential learning in the classroom.

Initially, students tend to draw upon familiar game structures and mechanics, such as trivia-style games or games that involve moving along a path and answering questions. However, through an iterative design process involving feedback sessions, playtesting, and refinement, students gradually develop more sophisticated and meaningful game designs that better reflect the entrepreneurial concepts they are learning. This process helps students develop adaptability, resilience, and critical thinking skills as they evaluate and improve their initial ideas and prototypes.

The influence of popular board games, such as Monopoly (Darrow and Magie, 1935), Risk (Lamorisse and Levin, 1959), Catan (Teuber, 1995), and The Game of Life (Klamer and Markham, 1960), is evident in the games designed by students. These classic games often serve as a foundation for students to build upon and modify as they incorporate entrepreneurship concepts and ideas. This approach exposes students to interdisciplinary learning as they apply and reconfigure their knowledge from various business subjects to create games that engage players while teaching and reinforcing the concepts and ideas studied in their program.

Incorporating students' personal backgrounds, experiences, and observations from their own lives is another common element in the game designs. This approach fosters cultural awareness and empathy among students, as they become more aware of the diverse challenges faced by entrepreneurs in different contexts. By reflecting on these challenges, students develop a deeper understanding of the complexities of entrepreneurship.

Group work and communication play a significant role in the game design activities, fostering teamwork, collaboration, and negotiation skills among students. They must effectively communicate their game concepts and designs during the development process, pitch ideas, provide and receive feedback, and present their final projects to peers or instructors.

Additionally, game design activities require students to plan, coordinate, and execute their projects within specific timeframes and constraints, developing their project management skills. This, combined with the problem-solving skills required to address various challenges such as balancing gameplay and integrating educational content, contributes to the overall growth and development of students as future entrepreneurs and professionals.

In summary, the game design activities within the context of entrepreneurship education provide a platform for students to develop a range of skills and competencies, including creativity, innovation, problem-solving, collaboration, critical thinking, adaptability, communication, project management, interdisciplinary learning, cultural awareness, empathy, and design thinking. By engaging in these activities, students not only enhance their understanding of entrepreneurship concepts but also prepare themselves for success in their future careers and endeavours.

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Computer Games as a Pedagogical Tool for Creating Cyber Security Awareness

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Abstract: Cyberattacks are increasing world-wide, both on corporate networks and public institutions network. During 2022 hackers were widening their aim to target business collaboration tools such as Slack, Teams, OneDrive, and Google Drive with phishing exploits, making for a rich harvest of sensitive data given that most organizations' employees continued to work remotely. In the later years we have also seen academic institutions becoming more frequent targets for both cybercriminals and state sponsored hackers. In 2022 the education/research sector was most attacked industry globally, seeing a 43% increase compared to 2021, with an average of 2,314 attacks per organisation every week. Schools and universities have the unique challenge of dealing with children or young adults, many of which use their own devices, work from shared locations, and often connect to public Wi-Fi without thinking of the security concerns. Additionally, Russia's war on Ukraine has led to an increase in spear-phishing activity targeting educational institutions in NATO countries. This situation calls attention to the need for awareness raising about personal cyber security. In Norway, Nord University is one of a few universities with specific focus on security and preparedness, including cyber security awareness. The university has two information security courses: one belonging to furthering education and one within the MBA-study program in Security and Preparedness Management. This paper examines the question whether serious games and online quizzes can create heighten cyber security awareness and motivate individual students to change their cyber security behaviour. The paper reports on the findings based on written reflection notes from students belonging to both courses. The technique of examination and interpretation applied to the data was qualitative thematic content analysis supported by computer-assisted qualitative data analysis software NVivo. Theoretical analysis was guided by social constructionist perspective on knowledge creation. While many advantages of the use of online quizzes and computer games were specified by students, challenges were identified as well. However, the findings show that the use of serious games and online quizzes can be an efficient approach to raising security awareness among participating students.

Key words: Information security, Cyber-attacks, Awareness raising, Serious games, online quizzes

1. Introduction

Core issues in the research on cognitive effects of video games were identified as early as in the mid-eighties when the early attempts were made to introduce theoretical rigor to understand the relation between playing video games and the development of thought. The result of this early investigation was the discovery that complex cognitive skills are required to play video games with success. Furthermore, a cognitive by-product of gaming was identified and defined as a new type of literacy for the technological age (Greenfield, 1984). Since then, it has been convincingly argued that games promote student motivation and engagement (Gee, 2007; Greenfield, 2010) as well as provide good arena to teach twenty-first century skills (Squire, 2006). In the big picture, digital games are environments for studying key processes involved in learning and gaining insight into how learning occurs (Gee, 2003; Gee, 2004; Gee 2005; Gee, 2007).

In the recent years computer games have also emerged as an increasingly powerful tool for pedagogy in cyber security education, providing better understanding and retention of cyber security concepts. Research has shown that computer games can enhance students' knowledge, skills, and attitudes towards cyber security by simulating real-world cyber-attacks and providing a safe environment to experiment with concepts without causing harm to actual systems (Alotaibi et al., 2016; Coenraad et al., 2020).

As cyberattacks are increasing world-wide, both on corporate networks and public institutions network, the importance of training students in information security has never been higher. This paper examines the question whether serious games and *online quizzes* may have an impact on creating a heighten cyber security awareness and motivate individual students to change their cyber security behaviour.

2. Background

2.1 The Cyber Security Courses at Nord University

At Nord University there are two cyber security courses: "ICT1013-Basic information security" belonging to a furthering education study program in ICT and Learning, and "ORG5005-Digital preparedness" belonging to the MBA-study program in Security and Preparedness Management.

The course "ICT1013-Basic Information Security" serves as an introductory course that covers fundamental terms and subject areas related to information security. The objective of this course is to enhance students' awareness regarding their responsibility for digital preparedness, both as private individuals and employees. The academic content of the course encompasses an elementary comprehension of computers, diverse cloud services, and the significance of digital preparedness. The course "ORG5005-Digital Preparedness" provides an in-depth understanding of current digital threats and vulnerabilities, along with relevant protective measures for daily preparedness and incidents within the upper crisis spectrum. The course aims to trigger reflective thinking in students to improve their emergency management skills and overall security consciousness as citizens of a predominantly digital society, rather than providing training to combat hackers, whether they are criminal or state actors. The intention is for students to comprehend that their own attitudes and digital preparedness play a crucial role in enhancing the overall preparedness of their employers and the nation. Additionally, students should be capable of conducting awareness-raising activities in their organizations and participating in preparedness exercises that encompass the loss of digital infrastructure.

Both courses use a set of computer games and online quizzes to enhance the students understanding of cyber security threats. The games were presented to the students in the form of an obligatory task where the students both had to play the games as well as analysing them based on relevant academic papers. The students were also asked to describe weather or not playing these games had any effect on their own cyber security awareness.

2.2 The Computer Games and Online Quizzes Used

“Can you spot when you’re being phished?” Is a quiz created by Google's Jigsaw team with the aim of educating individuals on how to identify phishing attempts. The quiz presents elaborate phishing messages visually and prompts users to ascertain if they are being phished. It enables users to enhance their skills by practicing the technique of hovering the mouse over links to display the actual web address. Furthermore, users can scrutinize email headers and attachments, as displayed in the screenshot below, to authenticate the credibility of the message.

The Norwegian National Communications Authority has developed a cyber security assessment tool titled "How Exposed Are You to Identity Theft?" This platform allows individuals to assess their adeptness in protecting personal data and evaluate their competence level in safeguarding against identity theft by undertaking a self-evaluation test.

"The Weakest Link: A User Security Game" was created in response to the findings of IS Decisions' research, which indicated that 48% of IT professionals consider training as a crucial factor in enhancing user security awareness. Furthermore, 38% of the professionals desired more innovative training materials and content. The game employs a question-and-answer format that is reminiscent of a "choose your own adventure" style. Its objective is to navigate through the first month of working for a fictitious employer without making too many security mistakes. Each working day presents a distinct scenario, and players are provided with response options. Points are awarded for selecting secure options and deducted for selecting non-secure options. The aim of the game is to complete the month without incurring a significant loss of points.

“The Cyber Awareness Challenge” was developed by the US Department of Defence (DoD) and aims to influence behaviour by emphasizing actions that authorized users can take to mitigate vulnerabilities and threats to DoD Information Systems. This training is both up-to-date and engaging, with a user-centric approach. The Cyber Awareness Challenge serves as the standard end-user awareness training for the DoD, providing awareness content that addresses emerging requirements from Congress, the Office of Management and Budget (OMB), the Office of the Secretary of Defence, and the DoD CIO chaired Cyber Workforce Advisory Group (CWAG). The course furnishes an overview of current cybersecurity threats and best practices to safeguard information and information systems, both at home and in the workplace. Furthermore, it reinforces best practices to protect classified information, controlled unclassified information (CUI), and personally identifiable information (PII).

3. Research design

The objective of the undertaken research was to explore students’ perceptions of their own cyber security awareness and whether playing the games/quizzes would lead them to change their cyber security behaviour. The assumption was that the undertaken investigation may provide some insight regarding possible advantages and disadvantages of using serious games and online quizzes as part of cyber security education.

3.1 Participants

Participants in the study were forty-three students in the online course "ICT1013-Basic information security" and forty-nine students in the online course "ORG5005-Digital preparedness" in the academic year 2022/23. Students in the course "ICT1013-Basic information security" are predominantly professionally trained and active teachers while students in the course "ORG5005-Digital preparedness" are professionally trained and active officers and non-commissioned officers of the Norwegian Armed Forces, police officers and managers from various public and private organizations with management responsibilities for national or local preparedness.

3.2 Data Collection

The data were collected from students' reflection documents. Writing reflection documents is a part of each assignment in both online courses. Reflection documents are metacognitive components in students work which require introspection and self-analysis and, in assumption, lead to self-regulated learning with a high level of students' agency. The presented analysis focused on the parts of documents where students were reflecting on the strengths and weaknesses of serious games and online quizzes as tools for creating cyber security awareness, and changes in their own cyber security behaviour.

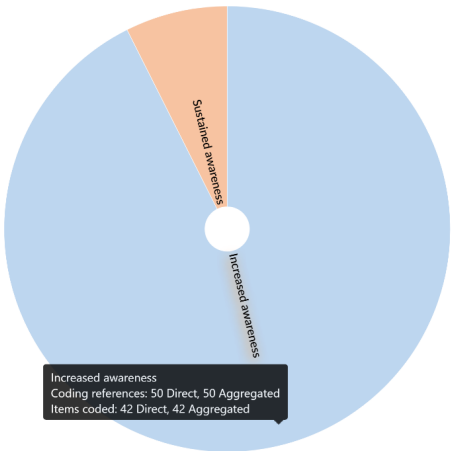
3.3 Data Analysis

The analytic method applied to the data was thematic analysis (TA). Thematic analysis is a qualitative research method aiming at exploring and identifying repeated patterns of meaning (themes) across a dataset. It is a theoretically flexible method used to address research questions related to people's experiences, views, and perceptions (Braun and Clarke, 2006). Conducted analysis was approached from the perspective of constructivist grounded theory and based on the assumption that "we know the empirical world through language and the actions we take toward it" (Charmaz, 2012).

Data analysis was conducted inductively, i.e., without using preconceived codes and categories. Assumptions were data driven. It was crucial to understand participants' views and their own perspectives and therefore follow grounded theory mandate. Data analysis was assisted by qualitative data analysis software (CAQDAS) NVivo.

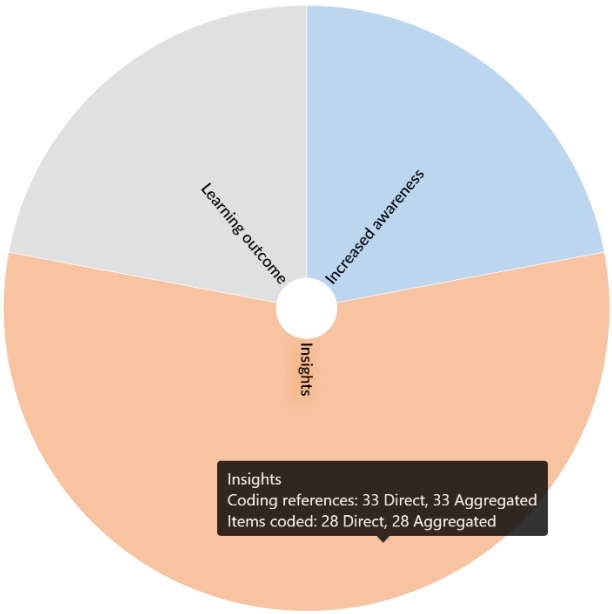
4. Results

The analysis of data revealed noticeable differences in the perceptions of the game and online quizzes related experience between the two groups of students. In the course "ICT1013-Basic information security", 98% of students (42 out of 43) explicitly pointed to increase in their cyber security awareness after playing the games and online quizzes required by the assignment (Fig. 1). Game experience, through the element of participation in the cyber security related situations, made them realize not only the gaps in their cyber security knowledge but also how important cyber security measures are and how broad the spectrum of cybercrime can be. The areas of cybercrime specifically reported by students as them being less vulnerable to after playing the games and online quizzes were fraud and theft identity.



Name	Files	References
Sustained awareness	4	4
Increased awareness	42	50

Figure 1: Themes that emerged in the reflections form students in the course "ict1013-basic information security". Source: CAQDAS



Name	Files	References
Learning outcome	11	13
Insights	28	33
Increased awareness	12	13

Figure 2: Themes that emerged in the reflections form students in the course "org5005-digital preparedness". Source: CAQDAS

Worth noticing is also the reflection that the game and online quizzes assignment helped students to develop better understanding and acceptance of cyber security rules at their workplaces. Before playing the games, they tended to prioritize focus on individual security over the focus on the cyber security at their organizations.

Conversely, in the course "ORG5005-Digital preparedness" only 24 % of students (12 out of 49) reported increased cyber security awareness after the game and online quizzes assignment. Interestingly, students' reflections in this group were more focused on games and online quizzes as educational settings, with 57% of students (28 out of 49) stating that games and online quizzes can be effective tools for raising cyber security awareness (Fig. 2). Worth noticing are the reflections pointing specifically to what type of games and online quizzes would best serve this purpose; they need to be realistic with themes and scenarios tailored to the individual organization, and preferably using Norwegian language. The participants highlighted the importance that the game and online quizzes scenarios focus on cyber threats and situations that feel relevant to the organizational needs. Perceptions concerning educational potential in computer games and online quizzes were labelled as "Insights" based on the words and phrases students used to express them: "I saw advantage …", "I realized games potential as learning arenas", "I acquired deeper understanding of how games, as a practical activity, can be supportive to learning theory". Furthermore, in the course "ORG5005-Digital preparedness" 22 % of students (11 out of 49) pointed to increase in their learning as an outcome of playing games and online quizzes. We may naturally assume that increase in learning also took place in case of 98 % of students in the course "ICT1013-Basic information security", which would be in an evident correlation with the increased awareness reported by students in this group. What is however interesting, students that are teachers by profession were more preoccupied with gaps in their knowledge, i.e., what they were not aware of than the knowledge acquired.

5. Discussion and Conclusions

In this paper we have explored the reflections of students participating in two cyber security courses at Nord University, Norway. While the students in the course "ICT1013 - Basic Information Security" specifically pointed to an increase in their cyber security awareness after playing the games, the students in the course "ORG5005 - Digital Preparedness" were focusing more on games and online quizzes as an educational platform for achieving goals such as raising digital security awareness. A possible explanation for this discrepancy is that

students in the course "ICT1013 – Basic Information Security" have a course "Digital Game Based Learning" in the same study program, and hence may already have a higher awareness of educational potential in computer games and online quizzes. For this reason, their attention was primarily directed to the content of the games and online quizzes and not the games as learning platforms. Also, students in the course "ORG5005 - Digital Preparedness" had evidently a higher cyber security awareness before they started working with the assignment compared with the students in the course "ICT1013 – Basic Information Security". For this, when required to reflect on the impact of games and online quizzes on learning, their dominant observation was that games can actually be efficient learning environments. The important conclusion for us is that both groups of students find the use of computer games and online quizzes valuable in cyber security training, and their reflections give ample grounds for further work in this field. One of the focal points in our work will be to select computer games and online quizzes that are more tailored to the specific needs of two students' groups. For the students in "ORG5005" we may investigate games and online quizzes which focus more on technical security measures, while the students in "ICT1013" may benefit from games and online quizzes with a clearer focus on the importance of human factors in cyber security, such as risky user behaviours and lack of motivation to follow internal security rules. To gain deeper insights it will be also important to examine students' reflections in several cycles of coding. This could inspire further ideas for improvements and following actions in the area of security, which remains a critical issue for both individuals and organizations.

Interpretative research, as the one presented in this paper, is prone to biases as the involved researchers can be, and usually are, a participating element of the research process and research results. There may be as many ways of 'seeing' the data as one can invent (Dei, 1993). This brings about the issue of the verifiability of qualitative data analysis. The results of the presented study are meaningful from the perspective of the purpose statement, however, not generalizable beyond the data sets.

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Development of a 3D Immersive Game for Games and Systems Requirements Capture

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Abstract: Requirements collection and elicitation is generally recognised as an abstract and complicated area with a reputation of being underdeveloped in computing and games development graduates. It is a necessary component of computing programmes on all sides of the curriculum including software engineering, information systems and games development. One highly problematic factor is the differences between general functional software and a serious game for educational purposes and while both can be classed as software, they have entirely different purposes. Games-based learning applications have been developed for teaching requirements collection where the focus has been on gathering requirements for a software system and this has proven to be effective in some respects. This paper will focus on the development of a 3D immersive serious game for gathering the requirements for a game for entertainment and for learning. The development of the game will be informed by the creation of a serious games' development model taking into account: learning outcomes, pedagogical content integration, general content integration in relation to graphical assets for appropriate realism and immersion, scaffolding and support mechanisms and assessment integration in relation to assessment mechanisms. Case studies will be discussed for the 3D immersive game in relation to fitness for purpose in relation to an entertainment and a serious game and compared and contrasted. The developed game will be evaluated by subject matter experts to ascertain its levels of effectiveness for gathering requirements for an entertainment game and for a serious game.

Keywords: Serious game, System requirements, Game requirements, Design, Requirements elicitation

1. Introduction

Requirements capture, requirements elicitation and requirements collection and analysis are highly important phases in the software development lifecycle and database application lifecycle but is often neglected (Gul et al, 2021; Knauss, Schneider and Stapel, 2008). If the requirements for a system/game are incorrect, then the client/player is dissatisfied, and this incurs greater expense the further along the development process by being more troublesome to correct. Development of functional software, computer games for entertainment and serious games are very different in terms of philosophy and approach. Traditional functional software is designed with the idea of efficiency in mind where the user fulfils their task and minimises their use with the software as much as possible. Games for entertainment have the completely opposite goal in mind where the idea it to elongate the players contact with the software (game) as much as possible and moreover to enhance lengthier playability. As a result, games tend not to have requirements perse but are a more creative, imaginative process involving fabrication. Serious games tend to sit in the middle of functional software and computer games for entertainment as they have a very specific purpose are generally contextualised and have a number of learning outcomes or training outcomes that have to be achieved on completion of the player playing the game. As a result, they have a creative process, however they are more specific in relation to contextualisation and learning requirements. This paper will review some of the previous work on games that have been developed for requirements elicitation and requirements collection and analysis and present a design and implementation of a 3D immersive game for requirements collection that is capable of incorporating a number of generic case studies.

2. Previous Work

Requirements collection and analysis is a highly important part of the software development and database application lifecycle. Requirements collection and analysis is probably more associated with the database application lifecycle and is defined by Connolly and Begg (2014) as "*The process of collecting and analysing information about the part of the organization that is to be supported by the database system and using this information to identify the requirements for the new system.*" It involves fact finding using various techniques such as interviews, document, and process analysis of an existing system to establish the requirements for a new computerized software system. While games are technically software they differ in terms of overall purpose and creativity with functional software normally resulting from a requirements specification with the requirements being fully or partially known. In any event gathering these requirements in general requires

various soft and abstract skills where the main techniques for elicitation are interviews, questionnaires, task analysis, domain analysis, introspection, repertory grids, card sorting, laddering, group work, brainstorming, joint application development, requirements workshop, ethnography, observation, protocol analysis, apprenticing, goal-based approaches, scenarios, and viewpoints (Zowghi and Coulin, 2005). Schön (1983, 1987) highlights key problems teaching an abstract subject of this nature:

- It is learnable but not didactically or discursively teachable: it can be learned only in and through practical operations.
- It is a holistic skill and parts cannot be learned in isolation but by experiencing it in action.
- It depends upon the ability to recognise desirable and undesirable qualities of the discovered world. However, this recognition is not something that can be described to learners, instead it must be learned by doing.
- It is a creative process in which a designer comes to see and do things in new ways. Therefore, no prior description of it can take the place of learning by doing.

In relation to software engineering and systems design, the main traditional teaching approaches are lectures, role-play, paper-based case studies and live-through case studies. It is important to understand the advantages and disadvantages of these approaches with regards to requirements collection and elicitation (Brooks, 1987). Studies that have investigated traditional teaching methods have been synthesized in Table 1 adapted from Bonwell (1996), Cashin (1985), Wehrli and Nyquist (2003), Davis (2001), the ADPRIMA Instructional Methods information website (2023), Biggs (1999), Shaw and Dermoudy (2005), Polack-Wahl (1999), Andrianoff and Levine (2002), Cope and Horan (1996), Bernstein and Klappholz (2001), Barrett (1997), Simsarian (2003) and Connolly, Stansfield, McLellan, Ramsay and Sutherland (2004). Table 1 shows a compilation of the attributes of traditional teaching approaches rated on a low, medium, high scale. For a full discussion of traditional techniques see Hainey (2010).

Table 1: Attributes of traditional teaching approaches

Attributes	Lectures	Role-play	Paper-based case studies	Live-through case studies
Instructor has control of the learning, has to be an effective speaker and communicate the intrinsic interest of a subject through enthusiasm.	HIGH	MEDIUM	LOW	LOW
Participants are actively involved in the exercise provide experiential learning and deeper understanding to have a considerable lasting effect.	LOW	HIGH	MEDIUM	LOW
Can be time consuming and therefore not always practical.	MEDIUM	MEDIUM	MEDIUM	HIGH
Scales with larger numbers of students and/or quantity of material	HIGH	LOW	HIGH	HIGH
Can provide a model of how professionals address problems and questions.	HIGH	MEDIUM	LOW	HIGH
Can provide elements of variety, reality and specificity.	MEDIUM	HIGH	MEDIUM	MEDIUM
Likelihood of transfer to the real world is improved.	MEDIUM	HIGH	MEDIUM	MEDIUM
Appeals to learners who learn by listening.	HIGH	HIGH	LOW	LOW
Appeals to learners who learn by reading.	HIGH	LOW	HIGH	HIGH
Appeals to learners who learn from demonstration.	LOW	HIGH	LOW	LOW
Appeals to learners who learn from discussion.	MEDIUM	HIGH	LOW	LOW
Appeals to learners who learn from practice by doing	LOW	HIGH	HIGH	MEDIUM
Presents a risk for learners for example, tension or embarrassment.	LOW	HIGH	LOW	LOW
Allows the learners to identify the mistakes of previous developers, thus reducing the possibility of making the same mistake.	MEDIUM	LOW	LOW	HIGH

Attributes	Lectures	Role-play	Paper-based case studies	Live-through case studies
Provides a safe environment to increase practice experience when real life experiences are unavailable, for example highlighting client frustration.	MEDIUM	HIGH	MEDIUM	LOW
Immediate feedback is provided.	LOW	HIGH	LOW	LOW
Can give new perspectives on situations.	MEDIUM	HIGH	MEDIUM	LOW
Learners can apply newly developed analytical problem solving skills in their own time to find a large number of solutions for complex issues.	LOW	MEDIUM	HIGH	HIGH
Maintains the attention of the learner.	LOW	HIGH	MEDIUM	MEDIUM
Suited for teaching abstract, complex subjects, or higher order thinking skills such as values, motor skills, analysis and application etc.	LOW	MEDIUM	MEDIUM	MEDIUM
Takes into account that learners are at different levels of understanding and learn at different paces.	LOW	MEDIUM	LOW	LOW
Puts pressure on the learner to perform.	LOW	HIGH	LOW	LOW
May require a debriefing session.	MEDIUM	HIGH	MEDIUM	MEDIUM
Has to be well planned, monitored and orchestrated or it may lack focus.	MEDIUM	HIGH	MEDIUM	MEDIUM

3. Previous Games on Requirements Collection and Elicitation

Several serious games and games-based learning applications were identified in the areas of computer science, software engineering and information systems by Connolly, Stansfield and Hainey (2007) including: KMQuest, The Incredible Manager, Open Software Solutions and SimSE. A further study performed by Hainey (2009) identified other games including: SIM VBSE RPG-SE and Anti-Phishing Phil which were relatively mature games at that time. The research performed was looking for any relatively mature games used to teach requirements collection and analysis or more generally software project management and lead to the development and evaluation of a specially constructed requirements collection and analysis game (Hainey, 2010). Hainey, Connolly, Stansfield and Boyle (2011) performed an evaluation that game for requirements elicitation finding that games-based learning can be a suitable approach to teaching requirements collection specifically in relation to:

- Identifying user requirements
- Identifying system requirements
- Resolving conflict and seeking clarification.

Given the increased interest in serious games both from a developmental and research perspective, there has been relatively limited further advancement in relation to developing serious games or games-based learning applications specifically for requirements capture/elicitation and requirements collection and analysis when comparing it to a mainstream subject such as Maths in the past 13 years. This is possibly because of the widespread development of serious games in relation to more easily applicable topics where this may be exacerbated by the fact that abstract topics are difficult to teach in general but have to be particularly well planned in a serious game. Ibrahim et al., (2019) identified 10 serious games for requirements elicitation where only one of them was from 2019 and the rest were pre-2010, 2010 and 2011. Soo and Aris (2018) performed an overview of games-based learning in requirements engineering and discovered eight games where some are duplicates with the same sort of time frame ranging from 2003 to 2011 with very little reported between 2011 and the present. This indicates that very few games have been developed on this topic over the past decade. A highly interesting point to reflect on is what the activities associated with requirements elicitation entail in relation to learning outcomes. After performing an extensive literature reviewing and analysing the games discovered, Ibrahim et al., (2019) linked learning objectives to learning activity and the measurement to ascertain if learning had occurred. Table 2 presents these learning outcomes linked to measurements and game activity.

Table 2: Learning outcomes linked to game activity and measurements (Ibrahim et al., 2019)

Learning outcomes	Activity	Measurement
Discovering requirements	Identifying NPCs, documents, objects, and scenes in the game to collect the requirements	NPCs, documentation, scenes, objects, and observations correctly identified, and requirements collected.
Analyzing requirement completeness	Identification of any additional requirements not identified in the game	Percentage/number of correctly identified requirements. Number of additional requirements identified.
Analyzing requirement relevance	Determining requirements are correct	Number of correct requirements included and excluded from the final list
Analyzing requirement consistency	Determining if requirements are inconsistent	Number of correctly identified inconsistent requirements
Analyzing requirement practicality	Determining if requirements are impractical	Number of correctly identified impractical requirements
Negotiating final system requirements	Collaborative discussion with the learners about the requirements	Number of negotiated requirements that are acceptable

Very few full games for requirements elicitation, requirements capture, or requirements collection and analysis have been developed since 2011, however there was the development of a requirements application process model (Durugbro and Kalverkamp, 2012). Gul et al., (2021) performed a systematic literature review to identify gamification elements used in requirements elicitation and discovered the following techniques other than Problem-Based Learning:

- Trophies,
- Levelling Up,
- Medals and Scoreboards,
- Virtual Goods and Levels,
- User Profile and Storytelling,
- Activity Feed and Story,
- Voting/Voice,
- Feedback and Missions,
- Levels and Time Limit,
- Blocked Content,
- Teammates,
- Achievement and Gifting,
- Quest and Guilds or Teams,
- Voting Mechanism and Status,
- Penalty and Count Down,
- Count Down and Performance Graph,
- Novelty,
- Progression.

Garcia et al., (2018) performed a study at the University of Mexico utilising a game called Biyubi (the word meaning to explore, analyse and discover). The study focused on interviews and utilised 94 participants who

were randomly divided into an experimental and control group. The experimental group utilised the game while the control group utilised a traditional teaching approach. The game was more advanced than previous games developed in 2016 and was 3D and immersive with three simple learning outcomes. The results indicated that the motivation, satisfaction, and the learning experience of the students increased.

4. Game Design

The development of a serious game in Unreal Engine 5 is set to be an office environment for the purposes of situated/contextualised learning by providing authentic activity and assessment (Brown, Collins and Duguid, 1989). The game allows character customisation and players can choose between two different characters, male or female, and interact with approximately 10 NPCs, including a receptionist, manager, HR person, and others in various roles. The game features a questing/task system for players to complete tasks and a dialogue system for communication between the player and NPCs.

The 10 scenarios are designed to meet the needs of the project focused on the requirements elicitation process and using a serious game to achieve learning outcomes. The project aims to teach learners about the process of gathering software requirements, understanding different software development lifecycles, practicing interview and response skills, and adapting to changing requirements in real-world client situations. Each scenario is crafted to address specific aspects of these learning objectives. The scenarios are as follows:

Scenario 1: Office Orientation - Players become familiar with the office environment, colleagues, and company culture, which can impact the requirements elicitation process. Upon starting at the new office, the player receives a task to familiarise themselves with the workspace and meet their colleagues. The player must interact with different NPCs, such as the receptionist, HR person, and manager, to learn about their roles and gather information about the company culture and office policies.

Scenario 2: Health and Safety Awareness - Players identify potential hazards, indirectly learning about the importance of considering non-functional requirements such as safety. The player is assigned a task to identify potential health and safety hazards in the office. They must navigate the office space and locate hazards such as blocked fire exits, exposed electrical wires, or cluttered walkways. Once all hazards have been identified, the player must report their findings to the HR person (NPC) and discuss ways to mitigate the risks.

Scenario 3: Collaborative Project Planning - Players collaborate with team members, learning about their roles and responsibilities, and develop a project plan, which is a critical aspect of the software development lifecycle. The player is assigned to a new project team and must collaborate with other team members (NPCs) to create a project plan. The player needs to engage in dialogue with each team member to understand their roles, responsibilities, and potential dependencies. Based on the discussions, the player must then help the team develop a project timeline and allocate resources effectively.

Scenario 4: Gathering Requirements - Players practice the core skill of requirements elicitation by conducting interviews and collecting information from NPCs. The player receives a task to interview a client (NPC) who wants to develop a custom software solution. The player must use their dialogue options to ask open-ended questions and gather the client's needs, expectations, and constraints. They must then document the collected information and present it to their manager for review.

Scenario 5: Prioritising Requirements - Players learn to prioritise requirements based on importance, complexity, and dependencies. The player must participate in a group brainstorming session with other team members (NPCs) to identify potential features and requirements for a new database management system. The player must use the dialogue system to contribute ideas, discuss pros and cons, and reach a consensus with the team. The outcome of the session should be a list of prioritised features and requirements.

Scenario 6: Updating Requirements - Players experience the dynamic nature of requirements as they adapt to changing client needs. The player must manage a situation where a client (NPC) changes their requirements midway through the project. The player must first understand the new requirements by engaging in a dialogue with the client. They must then assess the impact of these changes on the project timeline and budget and negotiate with the client to reach a mutually acceptable solution.

Scenario 7: Requirement Validation - Player's practice validating and refining requirements to ensure they are accurate and complete. The player receives a task to identify and interview key stakeholders (NPCs) within the organisation to gather their perspectives on the development of a serious game. Through dialogue, the player must determine each stakeholder's needs and concerns and consolidate this information to create a comprehensive set of requirements for the game.

Scenario 8: Documenting Requirements - Players learn to create a well-structured requirements specification document for formative feedback and assessment. After gathering and documenting requirements for a software project, the player must present their findings to the project team (NPCs) for validation. The player must use the dialogue system to address questions and concerns raised by the team members and revise the requirements document as needed to ensure that it accurately reflects the stakeholders' needs and expectations. The final requirements specification should then be submitted for official formative feedback and assessment.

Scenario 9: Conflict Resolution - Players learn to navigate conflicts and find solutions, an essential skill when dealing with diverse stakeholder requirements and expectations. The player witnesses a conflict between two colleagues (NPCs) regarding a project decision. The player must intervene and use their dialogue options to understand the root cause of the disagreement, facilitate a constructive conversation, and help the colleagues reach a mutually acceptable resolution.

Scenario 10: Reflective Learning - Players reflect on their learning experience, considering feedback from their colleagues and assessing their progress in mastering requirements elicitation skills. The player's manager (NPC) schedules a performance review meeting. The player must gather evidence of their achievements and contributions to the company, such as completed projects or positive feedback from clients or colleagues. The player should interact with various NPCs to gather this information and compile it into a summary to present during the performance review.

By using a serious game, players can engage with the learning material in an immersive, interactive, and enjoyable manner. The game provides a realistic simulation of the requirements elicitation process, allowing learners to practice and apply their skills in a safe, low-stakes environment. This approach promotes experiential learning (Kolb 1984), enabling players to build their knowledge and understanding of the requirements elicitation process through hands-on experience, ultimately leading to better retention and application of the skills in real-world situations. The initial idea was to create a more immersive contemporary version of the requirements collection and analysis game by Hainey, Connolly, Stansfield, and Boyle (2011) and attempt to bring it into modern times. The idea was also to change the case studies to allow collection of the requirements for normal functional software, a serious game and a game for entertainment. A screen shot of the requirements collection and analysis game is provided in Figure 1 for comparison. Figure 2(a) and Figure 2(b) show a screen shot of the new game developed to modern standards i.e., an 3D immersive game.

Figure 1: The requirements collection and analysis game (Hainey, 2010)

Figure 2(a) and Figure 2(b): Screen shots of Cubicle Conundrums: Quest for Clarity

4.1 Games Design Document

The Games Design Document for the developed game is as follows:

GAME TITLE: Cubicle Conundrums: Quest for Clarity

GAME OVERVIEW: Cubicle Conundrums is an immersive serious game that simulates the software requirements elicitation process in an office environment. The game aims to teach learners about various aspects of gathering software requirements, navigating different software development lifecycles, and practising interview and response skills. The target audience for this game includes students, software developers, project managers, and other professionals interested in improving their requirements elicitation skills. The game will be developed for PC platforms.

GAME WORLD AND SETTING: The game is set in a contemporary office, featuring an open layout and various rooms representing typical office spaces. The game world is designed with low-poly assets and simple shaders, providing a stylised and visually appealing environment. The atmosphere is light-hearted, with humorous elements and familiar office stereotypes. The office includes areas such as a reception, meeting room, HR office, manager's office, dining area, kitchen, server room, cubicles, media room, storage rooms, and bathrooms.

CHARACTERS

Playable characters: The game offers two playable character options (1 male, 1 female) with distinct appearances and clothing options. The characters have similar abilities and interactions in the game world.

Non-playable characters (NPCs): The game features around 10 NPCs, including a receptionist, manager, HR person, and other colleagues in various roles. Each NPC has a unique appearance, role, and interactions with the player.

GAMEPLAY MECHANICS

Controls: Players can control their character using a keyboard and mouse or a game controller, following a typical third-person control scheme found in 3D games.

Interactions: Players can interact with NPCs and objects in the game, such as opening doors, collecting items, and interacting with screens. Players initiate dialogue with NPCs by pressing the 'E' key when close to them.

Quest/task system: The game features a quest/task system that assigns objectives for players to complete as part of the gameplay experience. The system is integrated into a user interface (UI) HUD display, with options for tracking tasks and a compass system to guide players.

Progression and rewards: The game progresses as players complete tasks, unlock new scenarios, and gain experience in the requirements elicitation process.

USER INTERFACE (UI) AND USER EXPERIENCE (UX)

Heads-up display (HUD): The game features a HUD displaying relevant information such as active tasks, compass direction, and interaction prompts.

Menus and screens: The game offers menus for character selection, settings, and other in-game options.

Control mapping: Controls are mapped to allow for seamless gameplay on keyboard/mouse or game controller setups.

Visual and audio feedback: The game provides visual and audio cues to guide the player and signal progress or successful interactions.

DIALOGUE SYSTEM

System overview: The game utilises a Blueprint/UMG-based dialogue and scripting system that enables developers to create dialogue content using data-driven design and a range of inline text formatting tools and configurable interface options. The system supports branching and non-branching dialogue styles.

Integration: The dialogue system is integrated into the game world using actors, actor components, and UMG widgets.

QUESTS AND SCENARIOS

The game features 10 scenarios, each focusing on different aspects of the requirements elicitation process, such as gathering requirements, prioritising, updating, validating, documenting, and resolving conflicts. Each scenario has a set of tasks and learning objectives that the player must complete to progress through the game. The game employs a save/load system to store progress for each quest, ensuring players can pick up where they left off in their learning journey.

5. Conclusions and Future Directions

Requirements elicitation, engineering and requirements collection and analysis is a highly abstract and difficult subject with many approaches including, identification of stakeholders, interviews, questionnaires, task analysis, domain analysis, introspection, repertory grids to name but a few. Serious games have now developed to the stage where they can be developed more easily utilising game engines, however, there has been very few games developed for this particularly important area in the past 13 years besides one highly advanced game yielding positive results to teach interviewing and stakeholder identification (Garcia et al., 2018). This paper has provided an overview of the development and design of a highly immersive serious game for requirements collection and analysis following on from research performed in 2010. The game developed in this project was demonstrated at a Games Development showcasing event with industry representatives/subject matter experts at the University of the West of Scotland in May 2023. The intricate level design of the game and highly detailed environment received exceptionally high praise from games industry representatives in relation to design. The game is now in the final stages of development where particular case studies associated with finding the requirements of a game for entertainment and the requirements of a serious game are being integrated into it in relation to endogenous, intrinsic content integration. The game will then be evaluated in a Serious Games course as well as a Computer Games Development Programme to determine if a serious game can be an effective tool for learning in this context. To some extent this has already been proven, however increased focus on whether the immersive experience is more effective and whether highly detailed case studies associated with games for entertainment, functional software and serious games can be effective in isolation. Performing comparisons between the case studies to ascertain if a serious game for requirements collection can be more effective in various scenarios is a potential future research direction given that modern serious games can be created with sufficient complexity in terms of pedagogical content, level design, graphics, audio and immersion.

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Students as Educational Board Game Designers: Learning Opportunities and Design Dilemmas

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Abstract: Even though there is a long tradition for letting students play and design board games in the classroom, there exist relatively few studies, which conceptualise how students can learn through designing educational board games. In this paper, I present a theoretical model, which can be used to understand and inform how students work with board game design activities, and how this may require them to address specific dilemmas and complexities in their design processes. The presented GEC model (Games as Educational Challenge) builds on earlier studies, but is presented here in an adapted version, which focuses specifically on students' game design processes. The GEC model is exemplified with empirical data from the large-scale intervention project GBL21: Game-Based Learning in the 21st Century (2017-2022), where Danish students (grades 5-8, age 11-14) across 19 schools worked with a design thinking approach to designing game tools that address specific challenges within the school subjects mathematics, Danish and science. The current study focuses specifically on a teaching unit with a 5th grade class, who had to design a board game that addressed challenges with toxicity in online communication. By using the GEC model as a framework for the analysis, the current study highlights three analytical themes concerning: 1) the students' ownership of their presented game design challenges, 2) balancing of game elements versus subject-specific aims, and 3) the legitimacy of creating board games within the context of specific school subjects. By stressing both design dilemmas and learning opportunities, the paper contributes to creating a more nuanced understanding of how students address and deal with different complexities, when creating educational board games.

Keywords: Board games, Learning game design, Primary school, Design thinking

1. Introduction

There is a long tradition in formal education for letting students play and learn through board games. However, until recently, board games have been relatively overlooked within research on games and learning, which has tended to focus mainly on digital games (Bayeck, 2020). Researchers in various fields are increasingly exploring board games as learning spaces (Horn et al., 2012; Zagal et al., 2006). Board games represent appealing spaces for learning because of the simplicity of the games' mechanisms, which are often fairly easy to understand and change, and the focused face to face communication that take place across the board. In this way, the affordability and accessibility of board games make them perfect for providing social and playful learning experiences (Wonica, 2017). The flexible and adaptable design of board games may also explain why this is a preferred game format among many student teachers (Lieberoth & Hanghøj, 2017).

In this paper, I wish to focus on *design-oriented approaches* to board games in the classroom, where primary students are invited not only to play and discuss games, but also to develop their own board game prototypes in response to subject-specific specific design challenges within e.g. mathematics, Danish (L1) or science education. By letting students take on the role as game designers, they are given opportunities not only to develop subject-specific understandings of the content of the game, but also to develop important design competencies such as empathy, modelling, ideation, and process management (Rusmann & Ejsing-Duun, 2020).

This design-oriented approach to working with board games in the classroom has been explored in other studies. One example is the Quest 2 Learn school, where grades 6-12 children work with a design thinking approach to game design, including board games, within a cross-disciplinary curriculum based on systems thinking (Salen et al., 2010). The Q2L school represents a rather unique example of rethinking games, learning, and design processes, which involved support from both game designers and educational researchers. Another example is a study by Cortés et al. (2022), which explores how adult participants are asked to "playfix" a broken game, where the players must eliminate waste material from various biomes of an interconnected water-based ecosystem such as a swamp, a beach, and a river. In the study, the participants knew outright that they would encounter design problems in the games such as ambiguous or missing rules that would interrupt their play, where there was no single correct way to fix these. The key results of the study were less about learning curricular aims, but more on (a) how the participants focused on problem identification, (b) demonstrated quick and sustained engagement with thinking as designers, and (c) drew from multiple designerly modes non-linearly. As these two examples show, the studies exploring design-oriented approaches to board games in the classroom tend to focus less on isolated curricular aims and more on learning general design competencies. In this way,

there seems to be less research on what learning opportunities and challenges K-12 students face, when asked to design board games within a curricular context.

The current study is based on empirical data from the large-scale intervention project GBL21: Game-Based Learning in the 21st Century (2017-2022, www.gbl21.dk), where Danish students (grades 5-8) across 19 schools worked with a design thinking approach to designing game tools that address specific challenges within the school subjects mathematics, Danish and science (Hanghøj et al., 2019). In this study, I focus specifically on a teaching unit with a 5th grade Danish class, who had to design a board game that addressed challenges with toxicity in online communication. In this way, I address the following research question: *How do 5th grade students experience the learning opportunities and dilemmas of designing board games within the subject-specific context of Danish?*

2. Theoretical Perspectives

Taking inspiration from the American philosopher John Dewey's (1933) pragmatism, design processes can be understood as forms of *inquiry* where you have to work with concrete materials as part of a questioning exploration of a specific problem (Rusmann & Ejsing-Duun 2021). Design problems are often complex and are also referred to as 'wicked problems', as it can be difficult to understand how the problem should be framed and where there are rarely obvious solutions (Rittel & Webber 1973). A design challenge can, for example, consist of developing a new food scheme for the elderly in a municipality or finding new ways to deal with problems with harsh language in online forums. Thus, design problems call for a special design skill or specific way of thinking, which includes the abilities to (Cross 2006):

- Solve ill-defined problems – e.g., how to get people to communicate properly on the Internet
- Apply solution-focused cognitive strategies – for example by removing the possibility of using certain words on social media that may seem offensive
- Use educated guesses and further substantiate them – for example by developing and testing certain functions on social media
- Use non-verbal media for modelling proposed solutions – for example by developing prototypes.

By enacting these design skills, design thinking constitutes a methodological framework that can help professional designers to create an overview and structure in the work of addressing complex design challenges (Rusmann & Ejsing-Duun 2021).

It is a key goal of Danish as a subject that students should be able to create multimodal productions, i.e., by moving from an initial idea to draft to final product, collaborating with others, presenting products, and getting feedback on them. At the same time, working with open-ended design processes may also easily become unmanageable or downright chaotic. This may explain why design thinking has started to become a mainstream pedagogical approach in school contexts as the methodology provides a structure that can break down unmanageable design processes into more tangible activities. This often happens by going through five design phases, which in the GBL21 project are described as: 1) exploration, 2) interpretation, 3) idea generation, 4) experimentation and 5) testing (www.gbl21.dk).

Understanding design processes as a form of inquiry means that for each phase of the design process the 'designer' (student) must be able to ask questions, form hypotheses which they test through a dialogue between ideas, preliminary testing of ideas through materialisations and feedback from the people, who the design is intended for. In the GBL21 project, the students worked with design thinking through the use of different game tools (both analogue and digital), which focused their investigations on certain types of game designs and at the same time enabled the students to subsequently test their concrete design proposals (Hanghøj et al., 2019). Design thinking thus framed a product- and development-oriented way of working, while the games constituted communicative and interactive tools which enabled the students to relate concretely and exploratory to complex design challenges.

3. Example: Design of Board Games About Online Communication

The current study is based on a teaching unit, which concerns the design of board games about online toxic communication. The teaching consists of 12-15 lessons aimed at 5th grade, where students work in groups of 4-5 members and start phase 1 by examining examples of positive and negative aspects of online communication. They do that, for example by examining comment tracks on YouTube channels of influencers or describing incidents on social media that they had experienced themselves, e.g., in the chat while playing *Counter-Strike*. In phase 2, the students must interpret the various statements and identify a more concrete problem that they

want to address in their design process. In phase 3, students get inspiration to come up with game ideas by trying out classic board games such as *Monopoly* or *Draw and Guess*. By brainstorming, students develop ideas for how to design their game, which they discuss before selecting an overall idea for their game design. In phase 4, the students experiment with developing a prototype for the game design, where they e.g., draw a game board, design game pieces, and make question cards that deal with their problem. The unit ends in phase 5 with the students testing each other's games and making suggestions to improve them.

Throughout the unit, the students work with online communication as a specific topic within Danish as a subject. At the same time, the unit can be geared towards a number of Danish subject goals, such as being able to search for and read online texts, understand board games as an interactive type of text, plan multimodal productions, write game guides, and make oral presentations of game concepts. During the unit, the teacher acts as a facilitator of the students' design processes, where she has an important task of driving the design processes forward and providing critical and constructive feedback along the way. From a design professional perspective, students work with various design skills that can be described as idea generation, planning, collaboration, and modelling of prototypes.

4. Methodological Approach

The current study is based on video observations and interviews in a 5th grade class during the unit of two weeks. More specifically, I followed the group of three Year 5 students (age 11-12) – two girls and one boy – in a teaching unit of work in their Danish L1 classroom autumn 2019. The group was designated by their Danish L1 teacher as a well-functioning group and chosen for this reason. Consent was obtained from both the teacher and the parents of all students in the class. The class was one of four classes at four different schools that we followed as part of the qualitative track in the research project Game-Based Learning in the 21st Century (GBL21, 2017-2023). Prior to my observations, the teacher had participated in project workshops, where she had been introduced to working with design thinking and game design. Based on the workshops, the teacher had asked the students to complete a simple game design challenge, where the students had to redesign tic-tac-toe from a two-player game into a well-functioning game for three players.

In the teaching unit, which I focus on in this paper, the students were faced with a specific assignment or design challenge: They were asked to design a board game that should address and potentially help players to understand (and manage) issues with online toxic language. In this way, the unit both aimed at developing the students' design competencies and their understanding of online communication. Following a design thinking approach, the unit of work consisted of activities in which the students were to: explore examples of online toxic language (e.g. negative comments on famous YouTubers' videos or use of toxic language during in-game chat when playing *Fortnite* or *Counter-Strike*), interpret their findings, try out different board games as inspiration, generate ideas for their board game, experiment with (re-)designing a board game prototype, and evolve the prototype by testing it with other students. It should be noted that the development of a board game in Danish (L1) is not a typical classroom activity in Denmark. Rather, students are more likely asked to solve assignments, which involve reading texts or writing answers to predetermined tasks in the Danish L1 classroom (Fougt et al., 2020).

The focus of the qualitative study was to concentrate on idea generation. Data in this study was collected at three visits during the two weeks in which the teaching unit was carried out in this class (around 18 lessons). The data consist of field notes written on a laptop and assisted by video and sound recordings of classroom activities and group activities, following specifically the group in focus. Furthermore, photos were taken of both classroom and group activities, and all students' board games in the class, as well as their drawings, writing and other products were likewise collected through photos. The three focus group students were interviewed individually about their developed board game, their experience with collaboration in the group, and their experience with the unit of work and the way of working. Finally, the teacher was also interviewed before and after the teaching unit about her overall experience of the students' participation in the board game design processes.

Based on transcriptions, coding, categorisation, and thematic analysis (Braun & Clarke, 2006), three analytical themes emerged, which concerned specific dilemmas and learning opportunities when students design board games within a curricular context.

5. Theoretical Perspectives

In order to provide a detailed understanding of the learning opportunities and design dilemmas involved, when students design educational board games, I wish to conceptualise how students identify and frame *game design challenges* in relation to local educational aims.

Generally speaking, a challenge signifies a call or invitation to participate in a demanding situation. Consequently, games are designed to offer challenges that involve a sense of *agency* (Plass et al., 2015; Deterding, 2015). Often, design challenges involve coming up with possible design solutions to more or less open problems. However, the process of designing educational games can be viewed as a double design challenge, as the goal is both to create a playable and functional game on a given topic, but also to offer the player with meaningful challenges to be overcome (Deterding, 2015). In an educational context, the notion of a game design challenge might then refer to (1) the possible in-game challenges embedded in a specific game design by the game designer, (2) the players' interpretation, acknowledgement, and exploration of specific game challenges, and (3) the teachers' linking of specific game design challenges to educational aims (Hanghøj, 2022).

Following the work of Schön (1983) on how professional practitioners think and work, game designers should be able to address game design challenges by naming (identifying) and framing specific approaches that address unexpected situations or problems. In this way, game designers should not be seen as rational problem-solvers, as it is impossible to apply pre-defined knowledge which can cater to all the unexpected situations that arise when designing educational games. Instead, educational game designers need to *set* the problems for which they try to design solutions:

> *When we set the problem, we select what we will treat as the 'things' of the situation, we set the boundaries of our attention to it, and we impose upon it a coherence which allows us to say what is wrong and in what directions the situation needs to be changed. Problem setting is a process where we name the things to which we will attend and frame the context in which we will attend to them (Schön, 1983, p. 40).*

Moreover, educational game designers must be able to *reframe* problems or situations through reflection-in-action. Going through the processes of naming, framing, and reframing educational game design challenges is a highly complex practice and often involves considerable experience across game domains, subject-specific domains, and pedagogical domains (Hanghøj et al., 2022). In this way, there is a huge difference of expertise between being a professional designer of learning games and a 5th grade student trying to grapple with educational game design. Nonetheless, I argue that students will have to face some of the same challenges as professionals when trying to design educational games.

Drawing on the theoretical perspectives outlined above, I now present the Game As Educational Challenge (GEC) model in order to understand how students approach educational game design challenges. The GEC model (see Figure 1 below) is a general model developed for understanding how teaching with games requires the establishment of connections between game goals and curricular aims as well as design- and process-specific aspects of games, by taking departure in specific game challenges (Hanghøj, 2022). The adapted version of the model shown below is based on the assumption that students' design of educational games requires the participants to identify and to create meaningful links between selected game challenges and relevant educational challenges.

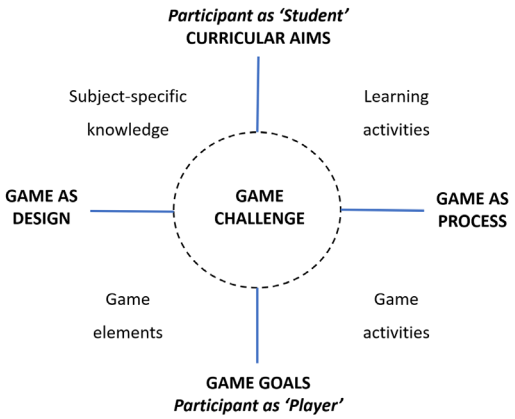

Figure 1: The Games as Educational Challenge (GEC) model. Adapted from Hanghøj (2022)

In this way, students need to orient themselves both to different types of aims shown on the vertical dimension (i.e., curricular aims and game goals) as well as different aspects of the design process shown on the horizontal dimension (i.e., the specific meanings, game elements and affordances of their game design and the different activities involved in making the game and how it should be played). The model is exemplified below in relation to the 5th grade teaching unit on designing games about online communication:

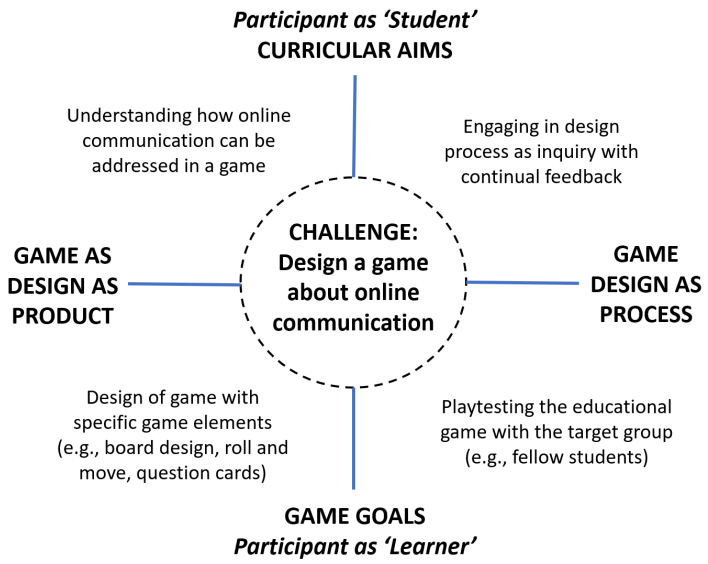

Figure 2: Exemplified GEC model in relation to the teaching unit

6. Analysis

The analysis is structured as three analytical themes, which all address learning opportunities as well as design dilemmas when the 5th grade students design board games in Danish as a subject: *1) whose challenge?, 2) balancing games and learning*, and *3) how is this "Danish"?*.

6.1 Theme 1: Whose challenge?

The first theme revolves around the students' perception of the game design challenge presented to them. Based on observations and interviews, it was clear that students were highly engaged in the design challenge. However, they also clearly struggled with the high degree of complexity of the overall design challenge, which they tried to break down in order to make it manageable. The data for the theme mostly comes from the first phase of the design process, where the students were introduced to the game design challenge and explored examples of online toxic communication in order to identify the key game design challenge (centre of the model, cf. Fig. 2). The teacher asked the students to locate several examples of online communication in order to identify the challenge (this corresponds with Schön concept of "naming"). The students examined, among other things, the negative comments on the Danish influencer Fie Laursen's YouTube channel and their own experiences with communicating on the social media TikTok or in online computer games such as *Fortnite* and *Minecraft*. The students were quite engaged in locating these examples, which they eagerly wrote down on post it notes and put on display on a shared poster in the classroom.

In the classroom discussions that followed this first phase, some of the students were surprised by the harshness of the toxicity found in online communication, while others were already familiar with the phenomenon. As one of the boys explained, harsh things are written online because "you can't hit back". The game design activity made sense in terms of developing the students' understanding of and creating ownership of the design challenge. In the subsequent interviews, one of the students put it this way:

> *Marie: I went to Fie's TikTok profile, and there was also an awful lot of hate with "disgusting pig" and all sorts of ugly things... I think it's bad that people write so many ugly things. [...]*
>
> *Interviewer: What do you think you have learned from this process?*
>
> *Marie: That I shouldn't write bad emojis to my father! […] I used to just write… all those bad [emojis] that were [on my iPhone] …*

The quote is an example of the students experiencing the design challenge with online communication as a "felt problem" (Dewey 1933), which was both based on new experiences through the unit and their own experiences outside of school. In this way, it was meaningful for them to work on dealing with the general problem of harsh tone by examining different platforms for online communication.

At the same time, the students' professional examination of the problem showed that they had relatively different experiences with the various social media platforms. Some students had extensive experience with toxic language on TikTok, other students had only experienced unpleasant language use in *Counter-Strike*, while others had not experienced the phenomenon up close at all. This points to a significant educational design dilemma: How should the students experience the design challenge so that it has both subject-specific relevance and immediate appeal and at the same time makes sense in relation to the students' various interests and experiences with the problem being addressed? In short: How does the game design challenge also become the students' and not just the teacher's?

6.2 Theme 2: Balancing Games and Learning

The next theme is mainly based on data from the game design activities, in which the students had to develop and select ideas for their game designs. This part of the unit was demanding for the students, as they had to both test (e.g., by playing) and develop an understanding of the game and design elements available to them, and at the same time try to come up with their own suggestions on how they could develop a game that could address their overall design challenge. At the same time, the students also had to balance their ideas for game designs, so that they both related to the subject-specific objectives and to the objectives of the game. In this way, it was often difficult for the students to balance their game ideas, so that they both included a focus on curricular aims (e.g., understanding online communication) and on creating a well-functioning game with clear goals (e.g., to obtain points or to get first when playing) cf. the vertical axis in the GEC model in Figure 1.

During the observations, I saw many examples of how the students tried to come up with and realise their ideas together. Sometimes students' game ideas focused on answering questions about how to behave online. Other times, they focused on giving the player physical challenges, such as push-ups, that had little to do with the subject of the game, but were meant to make the game more fun. At other times, the students developed ideas that created an entertaining game and at the same time related to working with toxic communication as a topic. As an example, the group I followed, developed the *Happy Emoji* game, where the player had to make grimaces that corresponded to the emojis that you land on, and thus experience different emotions when communicating online (cf. fig. 3).

Figure 3: The *Happy Emoji* game

Given the high complexity of the game design challenge, it is not surprising that the 5th graders did not always succeed in designing games with a strong link between game elements and curricular content. The research on games and learning shows that even professional developers of learning games often find it difficult to balance the two aspects in a meaningful way (Squire, 2006).

The interesting thing here is therefore not whether the students arrived at a 'correct' game design solution. Rather, the point is that the teaching unit positioned the students as designers, where they were faced with a

well-known dilemma within learning game design: How to develop games that balance the relationship between the goals of the game and the goals of the school subject? The students thus sought to both invent, negotiate, realise, and test design ideas based on the intention of creating a playable game with a clear goal (e.g., to come first or get the most points) and at the same time develop a game that could provide professional insight in problems with online communication (curricular aim) - cf. the vertical axis in the didactic game model in figure 2. By working with the dilemma, the students thus had the opportunity to gain concrete design experience in relation to developing and testing possible design solutions.

6.3 Theme 3: How is This "Danish"?

The third theme deals with how teachers and students experienced the game design unit as relevant to Danish as a subject. In the teacher-led class discussions during the unit, there was a tendency among the students to focus mostly on the quality of their game prototypes (game design as *products*) and they clearly had more difficulty putting into words and reflecting on their design *processes* – cf. the horizontal axis in the model in figure 1. This must be seen in the light of the fact that it was the first time that the students tried to work with the design thinking phases and that they were therefore not used to justifying and considering alternatives to their design proposals. The teacher experienced that the students "were turned on by the very idea of investigating online communication" (teacher interview). At the same time, it also became clear in my subsequent student interviews that the students only perceived game and design elements, game design solutions and design activities to a lesser extent as Danish subjects.

During the unit, the Danish teacher had asked the students to write a guide for their game, which should instruct others to play it in order to create a link to more familiar activities in the subject. In my subsequent student interviews, it was primarily the written work with the guide that was part of the subject-specific design solution, which the students highlighted as the Danish curricular content of the unit. The students experienced the other activities – searching and reading texts on the internet, investigating board games as a text type, collaboration, generating ideas, producing multimodal products, and presenting in class – as interesting and engaging, but not as recognizable ways of "having Danish".

In this way, the students' design thinking activities marked a break with their existing ways of having Danish. They only experienced a connection between new types of game and design activities and more familiar Danish subject activities to a limited extent. The students' experience of the unit thus points to a significant curricular dilemma in relation to working with design thinking in Danish: How can the teacher help the students to expand their understanding of the subject's practical forms in relation to working with design challenges and at the same time maintain continuity in relation to existing subject-specific practices? In this example, the teacher chose to emphasise Danish competencies in the unit by strengthening the students' written work with their game guides. Another way to deal with the dilemma of the unclear professionalism could be to make it clear to the students that the game design unit focuses on multimodal production, oral presentation, and online communication, all of which are central content areas of the Danish curriculum.

7. Discussion and Conclusion

Overall, both teacher and students were engaged in the unit, but the three analytical themes presented above at the same time testify that design thinking can be a demanding method to use in the Danish subject. The students thus had to both investigate and develop a relevant understanding of the design challenge, work 'hands on' to understand and use materials (game elements) and balance the idea development so that it met both the expectations of creating an entertaining and an educational game. Correspondingly, the teacher had to both frame and facilitate activities, so that the students had the opportunity to immerse themselves in their research processes, and at the same time also help the students to understand how the work with design thinking related to Danish curricular aims. In this way, both teacher and students had to juggle with many balls when trying to implement and negotiate the meaning of the unit.

The unit thus also testifies that the teacher must be able to scaffold, structure and respond to students' processes in the design unit. The game tools helped to engage and support the students' inquiry so that they could reshape and further develop their game ideas with relative ease. In the group I observed, the students' work processes were often intense and characterised by disagreements as well as time pressure before they reached the goal of a product they were satisfied with. At the same time, many of the students' design ideas could have been improved if they had prioritised their time differently or had received more feedback along the way from the teacher and their classmates. Open and creative design processes are by definition contingent and thus difficult to predict. Therefore, it is important – both as a teacher and as a student – from time to time to

stop, reflect, and put into words what is particularly demanding in the design phase you are in, and what you can do going forward to deal with the design problems you come across.

In this paper, I have described how design thinking can function as a valuable methodology in relation to addressing complex problems through Danish curricular design challenges. As the example shows, design thinking can offer a relatively tangible form of inquiry where students can investigate a complex problem by designing proposed solutions to it. At the same time, the empirical examples in the paper show how teachers and students also face dilemmas in relation to experiencing the design challenges as authentic, when balancing the design processes in relation to game-related and professional goals, and when relating the design activities to other Danish subject activities. It is therefore a significant task for the teacher in relating the benefits of the students' creative and partly unpredictable design processes to other ways in which the Danish subject is practised and assessed.

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Facilitating an Educational Board Game Jam: Analysing Different Game Design Strategies

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Abstract: There is a long tradition of using board games for educational purposes. Moreover, the growth of the game jam events where participants typically gather at physical locations with an aim of creating new games, has expanded over the last decades. This paper is based on an exploratory study, where we wanted to create a game jam for teachers, student teachers, facilitators, and consultants interested in designing and redesigning board games to enhance learning for different target groups. With a point of departure in design thinking, the game jam was framed through three phases: ideation, build a board, and playtesting. The participants were given the challenge of designing a board game incorporating co-op elements such as collaboration, problem-solving in teams, collective efforts towards a mutual enemy, etc. The game jam was held in a university college where the participants had access to a variety of materials such as pens, papers, cardboards, and discarded board games. The empirical data consisted of observations of participants, who were divided into groups of 2-4 persons based on their prior game experiences and game interests. The analysis presents preliminary findings in relation to the participants' different strategies for developing board games. The empirical data showed how the groups struggled to balance simplicity vs. complexity in their designs in relation to both time frame and target group of their board games. The playtesting session fostered discussions around the essential game mechanics and elements of each board game prototype. Furthermore, the ongoing feedback and playtesting created a joyful and curious bridge between the groups. Based on the analysis, the paper presents a series of design principles aimed at facilitating educational board game jams.

Keywords: Board game jam, Educational games, Design thinking, Facilitation, Learning, Collaboration

1. Introduction

There is a long tradition of using board games for educational purposes. Within recent years, there has been a growing interest both in playing board games as a leisure activity and using them for educational purposes. This interest is also reflected in the increasing number of studies on board gaming in educational contexts (Bayeck, 2020). It is possible to identify different pedagogical approaches to using board games for teaching. Based on the distinction of different game-based pedagogies put forward by Nouisanen et al. (2018), we can discern between: 1) the use of entertainment board games (e.g., *The Mind* or *Settlers*) for educational purposes, 2) the use of board games with more or less explicit learning content (e.g., using *Scrabble* for learning to spell or *Periodic* for learning the periodic system), and 3) learning through the process of designing educational board games. It is the latter approach that is the focus of this paper. We aim to explore the facilitation of a *board game jam* as a format for learning and game development, contributing to educational discussions. Our study may inspire educators and researchers while paving the way for future exploration.

A game jam is an event in which participants gather at a physical location with an aim of creating new games, which may be intended for entertainment or aimed at educational contexts. The aim is to create a workable prototype or complete game from scratch within a limited time frame, e.g., one or two days, and then share the results (Kultima, 2015). The format of game jams, which originated in informal settings outside education, has expanded over the last decades and has increasingly come to be viewed as a site for learning. Studies suggest that game jams may be pedagogically compatible with formal general education and are able to increase motivation and self-efficacy (Aurava et al., 2021). According to a review on game jam research by Meriläinen et al. (2020), game jams can be viewed as activities for developing technical skills needed for game development, but also for developing so-called soft skills such as collaboration and communication skills, and to teach and learn subject-specific content within science, technology, engineering, arts and/or mathematics.

Even though board game jams offer many possibilities for engaging in creative learning processes and the development of numerous skills through the co-creation of new game prototypes, they also involve several challenges to consider (Meriläinen et al., 2020). One challenge concerns the limited time frame of a game jam and how it fits into the time schedules of existing educational systems. Another challenge concerns the practical issues of planning, organising and facilitating game jams, where participants are invited into a safe environment, which provides them with sufficient support and guidance on their design processes as well as

relevant game tools and materials to work with. Finally, it is also important to consider the importance of the participants' game literacy, i.e., their prior experience as well as their knowledge and understanding of specific game mechanics or game formats. As a study on the use of games in teacher education has shown, student teachers' game literacy and motivations for playing games may vary significantly (Lieberoth & Hanghøj, 2017).

For the purpose of the current paper, we are mainly interested in how board game jams for educators can be organised and facilitated. By educators we refer broadly to a mixed group of student teachers, in-service teachers, pedagogical consultants as well as developers of learning materials. More specifically, we wish to explore the following research question: *How to facilitate an educational board game jam that addresses the participants' different prerequisites and support their different game design strategies?*

The empirical case for our study is based on observations and field notes from an open one-day board game jam for 30 educators that was arranged and facilitated at a university college by the authors of this paper. This means that we as authors have all taken on the dual roles of being both organisers/facilitators of the game jam as well as researchers that try to explore the participants' design processes. The theoretical perspective of our paper is informed by research on board games and design processes. Based on our analysis of how four different groups engaged in their board game design processes, we conclude the paper by presenting and discussing design principles for facilitating educational board game jams. The design principles concern: 1) The importance of having a clear "point of view" when developing an educational board game, 2) the need for developing a shared understanding of subject domain and game format, and 3) the balancing of game mechanics with learning content.

2. Method and Empirical Data

Our methodological approach to organising board game jams is grounded in Design-Based Research (DBR), which aims to generate local theories and develop new designs for learning through iterative cycles of design, use, and analysis (Barab & Squire, 2004). Moreover, DBR interventions often involve the development of design principles, which serve as guidelines for other researchers and practitioners, who wish to carry out similar design experiments (Hanghøj et al., 2022a). Following a DBR approach, the board game jam is considered a pilot study, and should be seen as an intervention, where we seek to both understand and develop the format of using board game jams for educational purposes. Researchers within DBR emphasise how design experiments can be viewed as sometimes reflective and sometimes prospective (Cobb et al., 2003). The analysis is based on reflections of our participatory observations while the discussion has a more prospective focus with the presentation of design principles.

As mentioned, the authors of this paper enacted different roles in the design experiment such as preparing for and carrying out the board game jam as well as conducting a retrospective analysis (Cobb et al., 2003) of the participants' design strategies. This places a demand of reflecting the challenging role as DBR researchers: "Design-based researchers are not simply observing interactions but are actually 'causing' the very same interactions they are making claims about" (Barab and Squire, 2004, p. 9). To address this challenge, we all made individual field notes during the board game jam where we also had different tasks as facilitators e.g., introducing the different design phases of the day. Afterwards, we compared and discussed our observations and patterns across were categorised into an analysis of participants' different strategies of developing board game designs.

The empirical data consists of participatory observations and pre-questionnaires answered by 30 educators / participants based on their experiences of developing games. At the jam, the groups were divided into groups of 2-4 persons according to the participants' game interests expressed in the pre-questionnaire. The programme of the day consisted of different phases inspired by design thinking which encouraged an iterative approach to game development (e.g. Kolko, 2010). The board game jam lasted 7 hours primary focusing on three design phases: 1) Ideation, 2) Build a board, 3) Playtesting.

3. Theoretical Approach

This paper takes a theoretical point of departure in the architect and educational researcher Donald Schön (1983) who argues for reflective practice to be privileged over technical rationality in all professional work. His theory is derived from the way architects work, going into dialogue with materials, that is going into a 'back-talk' of the situation (Schön, 1983, p. 79). Inspired by the ways architects and designers work through sketching their ideas, we encourage participants in our study to engage in an explorative conversation with the materials and other group members when developing and communicating their design ideas (Twersky & Suwa,

2009). Throughout the different design phases, the participants are given the challenge of developing co-op games which can be interpreted in different directions. Thus, the participants are tasked to actively set the stage for their game design according to their own game interest within the overall assignment. Schön elaborates how a large part of working as a designer is identifying the problem and the context for which a variety of solutions are carried out and tested. He emphasises: "Problem setting is a process in which, interactively, we *name* the things to which we will attend and *frame* the context to which we will attend to them" (Schön, 1983, p. 40). In the analysis, we will outline examples of the ongoing naming and framing of the situations carried out in the groups. Here, the participants actively negotiate their angles on developing a co-op game for educational purposes.

Based on Schöns theory, designer John Kolko (2010) explains how designers' intentional *reframing* of situations is essential to attend the design from different perspectives. Through an active exploration of seeing a design solution from a variety of perspectives, the designers can imagine the position of different target groups and negotiate meaning of their understanding of the design. Kolko also expresses how the work with materials and the activities of 'getting things out' (2010, p. 18) can help designers to identify and draw connections between elements. Here, inspiration can be derived from many different sources which can be bridged into a 'synthesis process', where the designers collaborate on deciding which elements are more important than others (Kolko, 2010). In our study, we ask the participants to draw on their prior experiences of gaming and development of game designs when naming, framing and reframing their game situations, including their divergent experiences of working with specific game mechanics, which refer to the various actions, behaviors and control mechanisms afforded to the player within a game context (Hunicke et al., 2004).

In contrast to professional board game designers, the participants in an educational board game jam will often have quite limited knowledge of and experience with the broad range of different board game mechanics such as, e.g., worker placement, player elimination or resource management (Engelstein & Shalev, 2022). In the words of Schön (1983), this means that the participants will have a limited *repertoire* of knowing specific game mechanics, and how they could be applied for pedagogical purposes. During the course of a board game jam, there is limited time for learning new game mechanics. This means that the participants will have to rely on their previous experiences with games and their existing subject-specific knowledge of the target game domain (e.g., mathematics or insurance policies), when trying to design educational games that create meaningful links between game mechanics and specific learning objectives. Given the short time frame of a board game jam, it is important that the participants are able to quickly establish strong links between their chosen core game mechanics and the learning objectives of their game design. A key factor here is the *complexity* of their game design ideas, which both relates to the complexity of specific game mechanics and the complexity of the intended learning outcomes of the game (Wardaszko, 2018).

4. Analysis

The analysis consists of four different examples of participants' strategies when developing a board game design. Each example is divided according to the main activities during the design phases, namely: *Ideation*, *Build a board*, and *Playtesting*. The groups got feedback on their game design from peers and facilitators throughout the day, but mainly during the playtesting at the end of the day.

4.1 From Initial Undefined Idea to a Playable Prototype

In this example, the group (hereafter Group 1) consisted of three employees from an insurance company. In their daily work, they had different roles: One employee being an issue expert in insurance while the two other employees were learning designers in their company. All three had a common interest in making a board game to support couples, who are struggling with economic questions such as division of property etc. after a divorce. As a point of departure, the group started the game jam with a joint theme and a clear point of view for the game, but no preparation of materials, expanded development of the specific game mechanics or game design.

Ideation: In this phase, the group members agreed not to "lose themselves in details" to get a game design finished by the end of the game jam. Based on concrete rules from a regulation document on division of property, they created expected dilemmas which newly divorced couples would have to address. Here, the roles in the game were clear, as they consisted of the main characters of the divorced couple and their insurance counselor.

Build a board: In the building phase, Group 1 became more concrete regarding the target group for their game design. They explained how the counselor was the primary target group of the game and the clients in the

roles of the divorced couples would be the secondary target group in the game. During the ideation phase, the group received feedback from another group that led to more focus on which possible incentives the parties of the divorced couple might have in a negotiation, e.g., regarding economy, friendship after the divorce, etc. Based on the feedback, they *reframed* and discussed different perspectives (Kolko, 2010) on the game seen from both the primary and secondary target groups' point of view. The group used different materials to create cardboard characters of the different roles in the game (see figure 1).

Figure 1: Cardboard characters (left) and the divorced couple's effects for division after the divorce (right)

Playtesting: In this phase Group 3 enacted play testers for Group 1 and vice versa. In the beginning of the playtest, the group discussed how the title of the game 'The pension battle' provided a stage for an interesting narrative in the game. The two members from Group 3 were given the roles of the divorced couple, while the issue expert in insurance from Group 1 played the counselor who frequently presented new cue cards and regulations for the divorced couple to act upon. The fact that the roles and effects (car, house, summerhouse, etc.) (see figure 1) were explicitly explained and materialised, made the prototype accessible for playtesting. The play testers clearly identified with the characters and enacted the roles of a divorced couple fighting using the materials on the table (see figure 2).

Figure 2: Playtesting of group 3's prototype

The outplayed scenarios led to laughter among the two groups and a relevant discussion on the complexity within the subject matter, e.g., how to balance a realistic scenario of a divorce, but also not to encourage participating couples to escalate a fight. Here the intention of illustrating players' different incentives was up

for discussion, also to encompass a reconciled intention among the players. How might 'an ideal division of property' looks like played out in a scenario, were suggested to be framed in a future redesign of the game.

4.2 From a Joint Point of View to Drowning In Complexity

The group consisted of two in-service teachers from different schools (hereafter Group 2). They had a common interest in developing a board game design revolving around the climate crisis. Thus, they quickly *named* the subject matter for their game design. The target group for the game was supposed to be students in lower secondary education in the disciplines of geography and social studies.

Ideation: The group started their ideation phase with one of the group members mentioning *Terraforming Mars* as a co-op game for inspiration when developing their own climate crisis game design. *Terraforming Mars* is a strategy game, where each player enact the role of an organisation with the goal of making Mars livable. The game is relatively complex (it is rated medium to medium-heavy on Board Game Geek) and requires approximately 2 hours playing time. Based on their inspiration, the group discussed four different roles for the students to take in the game, each representing a specific organisation: a politician from a political party, a doctor from Médecins Sans Frontières (MSF), a member of NATO, a member from the European Union (EU). The group argued for a minimal reading of rules while discussing time concerns for integrating this kind of game design in schools (2x45 mins/week). One of the group members brought an overview of different game mechanics which the group members discussed how to implement in the game.

In a short feedback session with Group 3, Group 2 had difficulty explaining the purpose of the game design. In this way, the group had an overall problem area that they wanted to address in the game (the climate crisis), but they lacked a concrete point of view in the game. The roles such as 'a member of NATO' were too broadly described and did not specify what actions the roles were able to perform in the game. In contrast to Group 1, it can be argued that Group 2 'lost themselves in details' in the game mechanics before they had a clear joint theme for their game design. Here, they intended the game design to contain too much complexity, which discouraged them from *framing* a manageable context for their game design idea.

Build a board: Shortly after the feedback from another group, Group 2 split up amicably as they were not able to come to an agreement on how to reframe their initial game idea. It can be argued that the balancing of subject matter, game mechanics and the requirements of the target group became too complex for the group to navigate. Eventually, they did not complete the build a board nor the *Play testing* phases

4.3 From a Clear Aim to a Discussion About Game Characteristics

In our third example, Group 3, consisting of two educators from a teacher education, the group members had a clear aim and point of view with their game. With a focus on the co-op challenge of the game jam, they wanted to create a board game where players were encouraged to discuss different teaching dilemmas to negotiate joint solutions.

Ideation: In the initial ideation phase, the group discussed different target groups for their game, but ended up with student teachers as their main target to discuss different dilemmas experienced in their daily practice, e.g., during their internships. Group 2 took inspiration from a popular Danish radio talk show, where ordinary people can ask three famous people for help regarding a current dilemma in their lives. However, the group adjusted the game to revolve around dilemmas from pedagogical contexts where all concerned should discuss the dilemma from different perspectives in a role play. In a short feedback session with Group 2, Group 3 explained an example of a predefined dilemma in the game: A group of student teachers had their class of students on a field trip to a museum and the atmosphere was very loud and chaotic. Afterwards, the museum complained to the school management about the visit, but confronted with the complaints the student teachers did not see the problem. Hereafter, different parties in the discussion of the dilemma were presented. Based on the presented scenario, the two groups discussed whether this idea could be characterised as a board game. The groups agreed on the strong focus on creating a narrative framing of possible dilemmas for the student teachers to enact and discuss afterwards. At the same time, the game concept lacked the use of other game mechanics such as being able to win or lose against a joint enemy.

Build a board: In the building phase, the group members in Group 3 further discussed the essence of their game stating that: "Some people might not see our game as a board game. It depends on which definition you have of a board game". Still, they continued their iterative process of making a synthesis between their different elements of inspiration (Kolko, 2010). They wanted to maintain the focus on dialogues around dilemmas, but with more focus on involving the players into the development of the co-op game. Therefore,

they *reframed* the context and roles in the game to not only concern predefined dilemmas. In the second iteration of the game, the student teachers themselves should take both the role as a proposer of dilemmas and as joining parties negotiating possible solutions on the dilemmas. In this way, the group members emphasised that the content of the game ought to be user-created.

Playtesting: In the playtesting phase, Group 3 had created a scenario of an expanded identity dilemma situated at an independent boarding school for secondary students. The prototype involved an A3 with the dilemma explained in writing on one side. Therefore, the playtesting began with Group 3 reading a lot of text for the play testers from Group 1 (see figure 3).

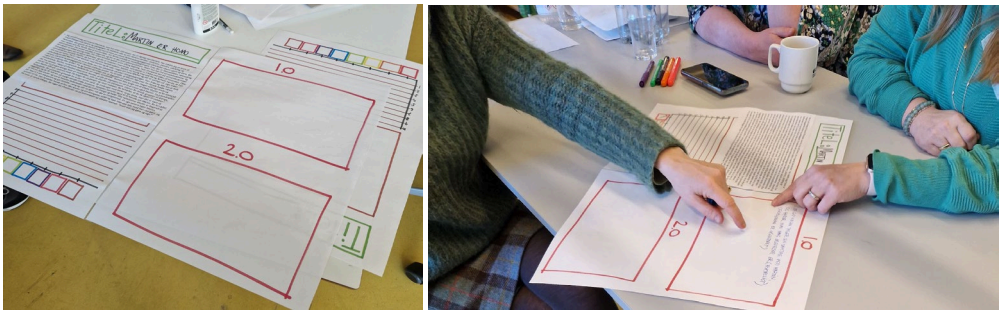

Figure 3: Group 3's prototype of their dilemma game (left) and playtesting of the prototype (right)

After the introduction to the dilemma, the members of Group 1 were given different roles in order to discuss different solutions; role as teacher, headmaster and student. To implement more game mechanics, Group 3 had added 10 points in the game, where Group 1 should decide who to give points according to which level of influence the player had in resolving the dilemma. The idea with points was explained as 'an experiment' and the relation to the framing of dilemmas was not entirely clear. However, the aim of providing a space for negotiating dilemmas were redeemed as Group 1 actively discussed the dilemma from a variety of perspectives enacting the different roles in the game (Kolko, 2010).

4.4 From a Developed Prototype to Refining a Game

Our last example concerns a group (Group 4), who brought an almost fully developed board game prototype to the jam, which they wanted to further test and refine. The group consisted of four: an independent learning consultant, an experienced science teacher and two science teacher students. They all had a strong interest in board games, and the latter three knew each other from working together at the same school.

Ideation: The group had chosen to work on refining a specific board game that aimed at learning secondary students about different types of energy supply. Thus, the *naming* of the core subject matter was clear from the beginning. In the game, each player should try to create as long supply lines as possible for a city using different types of energy. The group initially agreed that the game prototype was quite complex with many different game mechanics and layers of information (Wardaszko, 2018). In this way, the key focus for their design process was to further *reframe* and simplify the core mechanics of the game to make it more playable in a school context.

Build a board: During the "build" phase, the group explored different aspects of how the mechanics of the board could be further simplified. The main designer of the game had initially chosen to design octagon-square tiles as he believed that the hexagon-tile format was copyrighted. However, this format created "dead space" between the tiles and made it difficult to read the board. When the legal misunderstanding was cleared away, the group quickly designed hexagonal tiles for the board game, which created a more coherent visual impression (see figure 4).

Figure 4: This image shows how the group is leaving behind their original octagonal shaped game prototype idea (at the bottom) in favour of hexagonal shapes (at the top)

Playtesting: During the playtesting phase, the participants and facilitators focused on the game cards, which involved quiz questions for the students - e.g., on how to calculate effect or understand differences between direct current and alternating current. These questions were clearly relevant for the science curriculum, but they had no direct links to the player's actions and mechanics in the game. After discussing this lack of meaningful link between quiz questions and game actions, the group decided to drop the exogenous game elements (Squire, 2006) by removing the question cards from the game and instead focus more on the procedural learning that could result from playing the game and working with different types of energy supply.

In summary, the members of this group were quick to find a common focus and shared language for their redesign processes. Likely explanations for this were that the group members knew each other from beforehand, had a shared understanding of the subject matter and were quite experienced board game players.

5. Discussion

The analysis shows how the four groups used different strategies for developing educational board game designs. Briefly summarised, we saw analytical examples that included: a group moving through the whole process from undefined initial idea to playable prototype; a group that ended up "drowning" in the complex possibilities of their game design space; a group that developed a prototype, which they felt lacked sufficient game elements; and, finally, a group that mainly chose to refine and reframe an existing game prototype. Taken together, we have chosen these four examples to illustrate the relatively large variation that we observed during the game jam in the participants' different prerequisites and game design strategies. Following our DBR approach and the analytical examples above, we will now present three design principles, which all focus on the key role of the facilitators in organising and supporting participants during educational board game jams.

Design principle #1: Having a clear "point of view" when developing an educational board game

This design principle concerns the crucial process of being able to name and frame a game idea during the initial process of the game design process. All groups succeeded in naming their design challenges, but not all groups managed to frame their game ideas into successful game concepts. The facilitators need to support different starting points for the group processes by scaffolding questions and feedback accordingly. Some groups knew each other beforehand (e.g. Group 1 and 4) which most likely influenced how their strategies of naming a specific point of view for their game started before the ideation phase at the board game jam. It is also relevant to support and challenge dialogues for the groups to prioritise which challenges to be addressed in their design processes. For some groups the intended outcome of the game became too complex (Wardaszko, 2018) to navigate which led to stagnation in their game development, e.g., Group 2. On the other hand, Group 2 contributed to a relevant discussion with Group 3 regarding core elements of a board game. We consider these kinds of dialogues as a significant part of game jams for the participants to exchange point of

views and further develop their repertoire (Schön, 1983). Of course, with a focus of striking a balance where the progression in the game development is still central.

Role of facilitators: Supporting divergent and convergent design processes in terms of helping participants to open up the challenge, which they wish to address. Scaffolding of questions in the ideation phase to support a realistic framing of the intended challenges and learning outcome of the game. Facilitating space for participants to discuss different point of views on educational game designs.

Design principle #2: Developing a shared understanding of subject domain and game repertoire This design principle concerns the formation of groups, which can create a shared understanding of the topic (domain knowledge) as well as their game repertoire. This does not necessarily mean that all the participants should have the same knowledge or understanding of the domain or a similar game literacy. In fact, the participants in Group 1, which succeeded in creating a playable prototype of their game from scratch, consisted of a mix of expertise in the target domain and in design skills. Similarly, even though the members of Group 2, had a shared passion for the complex board game Terraforming Mars, they also had limited knowledge on how to address climate issues in a board game format. In this way, they had difficulties with complementing each other when designing a game for a complex topic on which they did not have deep knowledge. Based on the analysis of participants' strategies, we will argue that a group (or "design team") needs different skills and competencies to create a successful educational board game, which cuts across domain-specific knowledge, game knowledge and knowledge of the pedagogical context/target group (Hanghøj et al., 2022b).

Role of facilitators: Awareness on forming groups where participants can support each other and develop a shared point of view and shared understanding of subject domain knowledge. The use of a pre-questionnaires answered by the participants with a focus on their interests and experiences of developing games can support the division of groups.

Design principle #3: Balancing game mechanics with learning content

The final design principle concerns the balancing of game mechanics and learning content. As the previous design principle suggested, it is important for participants not only to mutually identify, but also to agree on how to simplify game ideas and core mechanics for playable prototypes that can fit with the constraints of educational settings - e.g., tight-packed time schedules, specialised curricular knowledge, and students with varying levels of game literacy. However, there is another aspect to this design principle, which concerns the removal of exogenous learning content, which has no clear or meaningful function within an educational game (Squire, 2006). This was particularly the case in example four, where the group refined their game design and decided to scrap test questions for the students that had no integration with the game mechanics and objectives of the game. Furthermore, for some groups (group 2 and 3) the level of text reading were questioned and discussed in relation to balance information load related to the learning content and the game mechanics. Here, a question of simplifying content and rules to have an appropriate level of complexity were a topic for discussion.

Role of facilitators: Scaffolding questions that bring awareness in groups about how to work with learning content suitable for the game context. Providing ongoing feedback for participants to simplify the game content into playable prototypes.

The limitations of DBR projects are that replication is difficult due to the study of a local context involving specific participants. However, by providing rich descriptions of context and the emerging design principles (Barab & Squire, 2004) our intention is to encourage further exploration on how to facilitate an educational board game jam. The robustness of the design principles would be strengthened when tested in new local contexts.

6. Conclusion

The aim of this paper was to explore how to facilitate an educational board game jam that addresses the participants' different prerequisites and support their different game design strategies. Analysis revealed differing approaches to iterative development and testing. Crucial factors included material use and balancing complexity in game mechanics and learning content for developing playable prototypes. Based on four identified strategies among the participating groups, the paper presents three facilitation-focused design principles for educational board game jams:

- Design principle #1: Having a clear "point of view" when developing an educational board game.

- Design principle #2: Developing a shared understanding of subject domain and game repertoire.
- Design principle #3: Balancing game mechanics with learning content.

To some degree, these design principles echo prior research on game jams (Meriläinen et al., 2020; Aurava, 2021) and research on how professional designers work when creating learning games (Hanghøj et al., 2022b). Our study emphasizes facilitators' pivotal role in planning, group formation, feedback, and evaluation. Retrospective, we suggest more guidance for groups who either drowned in complexity or lacked ideas for relevant game mechanics for their design ideas. The pilot study underscores the need for educational game jam facilitation to aid participants in creative processes. Our experience supports advocating multi-facilitator approaches, distributing tasks and leveraging individual expertise (Schön, 1983). Exploring facilitators' roles and prerequisites in educational game jams presents an intriguing topic for game researchers.

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Enter the Paraverse: Challenging Assumptions of Live Music in the Metaverse

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Abstract: The Metaverse, a concept and buzzword echoing throughout industry and academic spaces, does not exist. In this paper we theorize about the object that does exist: the Paraverse, the global set of disconnected virtual worlds and virtual world platforms working independently to advance virtual world technology and culture. We present a novel system within the Paraverse named Soundscape.social: a multi-user virtual world where participants explore concert spaces containing pre-recorded, synchronous performances by independent musicians during the early stages of the COVID-19 pandemic. Through its design and implementation, we demonstrate how small teams of independent developers may quickly contribute to the fringes of the Paraverse, and thus play an essential role in driving innovation. We assessed the platform's ability to foster communal listening experience through virtual ethnography, in-game data collection, and interviews with attendees and performers. Soundscape.social was successful at preventing abusive behaviour despite anonymous communication, respecting participant privacy through minimal in-game data collection, modelling anarchic community through a performance format that challenged hierarchical structures of listening, and fostering a novel understanding of liveness through listener autonomy and a novel asynchronous communication feature of interest we name "virtual graffiti." We further discuss opportunities for future work developing technologies that aid developers looking to create independent Paraverse applications, contributing to the future of virtual worlds and, perhaps, the Metaverse.

Keywords: Metaverse, Virtual worlds, Liveness, Covid-19, Social media

1. Introduction

If the apostles of web 3.0 are to be believed, the social internet is on the verge of massive change; we are about to witness the rise of a "decentralized" web built on blockchains, establishing infrastructure for a Metaverse: a theoretical network of interconnected virtual spaces where users may one day work, play, and, metaphorically, live. This phenomenon has revived interest in "virtual worlds," branded as new and inseparable from virtual reality. The Metaverse does not exist (Parisi 2021). More primitive virtual worlds do, and they will define the cultural imagination of the future metaverse's structure. We name this collection of virtual worlds, which lacks the interconnectivity required of the Metaverse, the *Paraverse*.

The resurgence of interest in virtual worlds was accelerated by the COVID-19 global pandemic, as the physically isolated masses pursued virtual socializing. Online games offered opportunity for social entertainment during the height of the pandemic (Cmentowski & Kruger 2020). Many used virtual worlds as replacements for specific in-person activities. Museums created virtual experiences to allow attendees to tour their physical spaces (Katifori et al. 2020). Conferences and classrooms turned to proximity-based video-conferencing platforms to reintroduce spatiality to poster sessions, networking, and lectures (Fisher et al. 2021, Latulipe 2021, Perego & Sebastiani 2021).

In this work, we present one such domain-specific virtual world: a virtual concert space for independent musicians. Musicians faced a multitude of technological hurdles while adapting conventional, collaborative, music creation and live performance to available remote methods like conferencing and live streaming tools (Cai et al. 2021). Particular creativity erupted around the concept of "liveness" itself, with some broadening its definition to include other forms of participation (Benford et al. 2021). Traditionally, "liveness" focused exclusively on performer participation. Our work departs from this completely, taking creating a platform focused almost exclusively on audience participation.

Our application, Soundscape.social, is a virtual world to listen to musical performances in 3D spaces with spatialized audio with other listeners. In designing it as a performance space, we embodied central components of the Musicircus, a work by American anarchist composer and indeterminacy pioneer John Cage. In designing it as a system, we embodied central principles of autonomy and power elimination, characteristic of an anarchist human-computer interaction methodology (Keyes et al. 2019). Throughout a three-concert series, we engaged in participatory design with performers, interviewed attendees, and performed virtual ethnography to inform iterative design.

Figure 1: A promotional image of the lobby of Soundscape.social's first concert

This work provides the following major contributions:

- A theoretical exploration of the Paraverse as a concept to challenge the Metaverse and advocate for innovation to aid small teams of independent developers in creating Paraverse applications.
- A novel system within the Paraverse named Soundscape.social: a virtual world designed to host performances by independent musicians.
- Features of Soundscape.social that may help other virtual-world designers through qualitative evaluation of our system.

2. Related Works

2.1 The Paraverse

The Metaverse was introduced in Neal Stephenson's 1992 dystopian science fiction novel, Snowcrash (Stephenson 1992), which takes place in a near-future anarcho-capitalist corporatocracy, the Metaverse a global social internet hosted on a network owned by the novel's villain. This Metaverse is a single, shared virtual environment that anyone may access as virtual avatar. From a more recent, wide-reaching literature review on the subject, we can understand today's theoretical metaverse as "an interconnected web of ubiquitous virtual worlds partly overlapping with and enhancing the physical world [which] enable users who are represented by avatars to connect and interact with each other, and to experience and consume user-generated content in an immersive, scalable, synchronous, and persistent environment" (Weinberger 2022, pg. 13). Though augmented and virtual reality technologies are often conflated with the idea of The Metaverse, they are not a requirement, per this definition (Weinberger 2022). The Metaverse is meant to be platform-independent (Parisi 2021).

Several companies with virtual world platforms are competing to own/become a part of the Metaverse, including Meta's Horizon Worlds, which offers virtual rooms and tools for collaboration, virtual socializing, and game creation. No single virtual world platform is THE Metaverse, nor would we consider them a part of the Metaverse (Parisi 2021), which does not and may never exist. In this paper, we refer to this existing collection of applications as the Paraverse. We define the Paraverse (from the Greek "para-", meaning "beside" or "between") as the global set of disconnected virtual worlds and platforms working independently to advance virtual world technology and culture.

2.2 Trouble in the Paraverse

Paraverse platforms are often driven, like much of the social internet, by user-generated content, and thus share a political economy problem, creating a culture industry built on unpaid, exploited labour (Terranova 2000). Social virtual world platforms such as Horizon Worlds and Roblox create an issue from the perspective of Free software rights (Stallman & Gay 2009); they allow users to create interactive applications and environments they cannot export outside of the given platform.

Content moderation issues and online harassment are problems across many of these Paraverse platforms. Roblox, a platform primarily used by children, has been the subject of repeated controversy over alleged exploitation of underage content creators (Parkin 2022) and failure to moderate sexually explicit content (Clayton & Dyer 2022). VRChat, a platform aimed primarily at adults, has allegedly failed to keep sexual content, as well as harassment, from reaching minors (Frenkel & Browning n.d.).

The projected over-centralization of the Paraverse, as companies like Meta capitalize on the trend, produces creative stagnation and the same issues of data security and surveillance that are major concerns in current social media, as in Meta's previous venture, Facebook. If platforms like Horizon Worlds expect users to move their social and work lives onto the platform, expanding opportunities for invasive data collection, this "migration" must come with increased trust in the platform, which Meta has not accomplished (Intelligence 2020, Kelly & Guskin 2021, Robertson 2020).

In Soundscape, we took the opportunity to build a system circumventing these issues. Instead of developing a world within an existing Paraverse platform or repurposing a game, we used a free game engine to create a standalone virtual world application. Our work serves as a model for an alternative wave of Paraverse applications built quickly by small, independent teams to drive innovation and challenge injustices in the space, as well as a novel system that offers design insights in the domain of virtual music performance and appreciation.

2.3 Challenges in Virtual Music Performance

The central design challenge of adapting a musical performance to an online format is that of using remote technology to emulate a feeling of liveness: the intimacy and immediacy characteristic of in-person performance and listening (Hook et al. 2012). We focus on four attributes of liveness of a happening:

- Temporality. It is ephemeral; one is driven to experience it right now (Couldry 2004).
- Exclusivity. Access to it is limited to the social group contributing to it (Couldry 2004).
- Spatiality. It occurs in a shared space, which may be corporeal or metaphorical, establishing proximity to the happening (Hook et al. 2012).
- Interactionality. It facilitates a social experience that is alive to a participant's presence (Harris 2017).

Through Tarumi et. al. (2017), we find key elements of in-person live performances are disrupted by moving to remote technologies, including novelty of a live show (due to mundanity, "Zoom fatigue" (Nadler 2020)), spatiality of audience viewpoint, and "sense of unity" among participants due to limited communication. Video games are a natural fit for this problem; they are categorically spatial and participatory (Murray 2017). Boellstorff's ethnography of Second Life, for instance, reveals spatiality and temporality in that players are constantly building relationships and shaping the environment of this virtual world (Boellstorff 2015).

John Cage's 1967 experiment in indeterminacy, Musicircus, forces us to reconsider liveness priorities in musical performance. Performances generally involve independent musicians, intentionally varied in genre and ensemble size, playing simultaneously in one shared space, as listeners freely move between performances and shape their own listening (Dickinson 2014). Improvisational and indeterminate qualities of Musicircus amplify its temporality, as the chaotic nature of composition and spatial autonomy of listeners makes it unlikely one could reproduce the exact auditory experience within and across performances. The playfulness of Musicircus is inseparable from its anarchist politics. The play of Musicircus establishes it as not an object but a process, which naturally resists cognitive totalization and commodification, instead offering a radical non-hierarchical performance model predicated on interpersonal relationships of "respectful non-interference" and "anarchic joy" (Junkerman 1993). Similarly, virtual worlds function as cultural models with embedded social theories through simulation of social, cultural, economic, and political systems (Bainbridge 2010).

In perhaps the most popular virtual music performance, Epic Games repurposes its multiplayer battle royale, Fortnite, to serve as a multimedia content delivery platform for concerts with well-known pop stars and DJs (Schober & Stadtmann 2020). Combat mechanics of Fortnite are temporarily disabled, allowing players to navigate a performance with elaborate visuals and peacefully interact with other players. Fortnite has hosted both pre-recorded and live performances, with the artist represented in the space either through video or as avatars. The audio has no spatial component; each player hears the same audio regardless of their position. Although artists call out to the audience to perform certain actions during these performances, like using particular "emotes," the artist has no clear ability to observe their audience, minimizing the distinction between live or pre-recorded performance.

The politics of Fortnite concerts are antithetical to those of Musicircus. Superficially, Fortnite is a platform for celebrity concerts, more of a platform for wealthy advertisers than one dedicated to musical expression. Listener self-expression requires the purchase of commodities, as expression is primarily facilitated by "emote" character animations, which players must individually purchase (Marshall 2019). Fortnite uses virtual world capabilities to amplify hierarchical relationships between performer and audience, with one concert even representing Ariana Grande as a larger-than-life figure with godlike control over the audience. While Cage's

Musicircus uses performance to explore an alternative future, Fortnite uses performance to celebrate consumer culture that defines the status quo.

With Soundscape.social, our ideal liveness was temporal, exclusive, spatial, and, primarily, rooted in listener agency. We looked to emulate the interactive successes of existing Paraverse virtual concerts but in a characteristically "indie" way in terms of production limited to a single software developer collaborating with independent musicians of only modest followings, and in anticapitalism, as an experience that substitutes pursuit of profit with heightened respect for individual autonomy and pursuit of anarchic joy.

3. Iterative Design and Development of Soundscape.social

3.1 Preparing the Initial Launch of Soundscape.social

Soundscape.social's format emerged through discussions with organizers at a local classical music nonprofit, Classical Revolution RVA. The following list expresses a high-level description of the application as it was originally devised:

- Soundscape.social is a free online virtual world application for Windows and MacOS where users experience pre-recorded concerts, synchronously.
- Each Soundscape.social concert contains four simultaneous performances, isolated to their own virtual spaces that resemble art installations, connected to a central lobby.
- Performers are represented by their instruments, pulsing in size proportionately to the loudness of their audio (Figure 2)
- Each space includes a plaque with information about the performers and the performed pieces.
- Users explore spaces from a first-person perspective but are represented on other users' screens as emoji 1)
- Users communicate with each other through anonymous notes they may place anywhere in the environment, which we call "virtual graffiti."

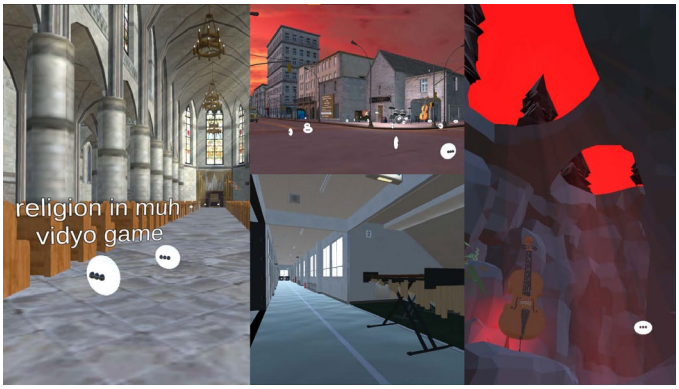

Figure 2: The performance spaces in Soundscape.social's first concert, "Soundscape.social: Opening Night"

At first glance, Soundscape.social appears like several preexisting virtual world applications, particularly those that released in the 2000s such as Second Life, PlayStation Home, and Habbo Hotel. Like these platforms, Soundscape.social is a video game focused more on players socializing in a persistent online space than anything resembling conventional gameplay conflict. Its departure from these prior works is mainly in highlighting the possibility of independently created virtual world applications rather than virtual world platforms. One likely could have hosted a virtual concert with the same music as the concert series conducted in this work within Second Life but this staging of the music would not offer the same degree of creative freedom offered when creating an independent application. Creative collaborators who helped construct Soundscape.social had a say over how audio would sound (such as use of an advanced spatial audio system), how the players move through and interact with the space, how players may communicate with each other, and various other parameters of the experience that would have simply been given as standard in virtual world platforms.

Soundscape.social was initially implemented by a single developer in Unity. Environments were assembled using readymade 3D models purchased for the project. We used Photon Unity Networking to quickly develop multiplayer features. For communication, we hosted a web application and database of note objects, which contain only text, the location where it was placed, sender IP-address, and a Boolean indicating whether this

note has been flagged as inappropriate, determined by a simple check to determine whether the note contains language deemed offensive. Users are never notified if their note has been deemed inappropriate but inappropriate notes are hidden.

3.2 Soundscape.social: Opening Night

The initial launch of Soundscape.social included the four performance spaces found in Figure 2. A trumpet and organ duo performed in a cathedral, a jazz trio on a city street corner, a percussion ensemble in a school hallway, and a solo cellist in a cave. The cave offered our first attempt at location-specific interactivity; it contained an interactive xylophone made of stalagmites.

Information about attendance is shown in Table 1. For the purposes of iteration, we employed informal virtual ethnography, immersing ourselves within audiences during the opening night for each version of Soundscape.social and analysed content and placement of audience messages. After each launch, we conducted informal interviews with two known participants to enhance user experience. Many observations following "Opening Night" sustained themselves as patterns throughout all concerts.

We recruited personal acquaintances whom we knew had attended the launch or were referred to other attendees for informal interviews. Interviewees particularly enjoyed the option to "fly" by pressing the spacebar repeatedly as it gave them a sense of freedom not afforded by an in-person concert. Interviewees appreciated the unique interactivity of the xylophone. Some players escaped the bounds of environments and left ironic messages to mark their achievement. Not all interactivity was well-received, however; players mentioned that they struggled with platforming challenges in the cave. Additionally, interviewees requested a more conventional chat feature as opposed to the purely localized notes, finding that it lacked immediacy.

We noticed as attendees and in conversation with interviewees that attendees performed a kind of "politeness." In addition to the positive demeanour of notes, players gathered in semi-circles around performances as if it were a corporeal event. There was visible effort to allow clear views of the performers, both in how players physically arranged themselves and how they avoided placing notes directly next to performer avatars. Players also developed imagined communities around objects and placed notes in spawn locations as impromptu tutorials for players who lacked game literacy.

Assessment of "Soundscape.social: Opening Night" led us to imagine the following additions for the follow-up iteration:

- Developed a text chat, displaying the text of notes on the heads-up-display.
- Added location-specific interactive elements in every performance space.
- Introduced a tutorial system. Text listing the game controls remains displayed until the player performs the given action.
- Designed spaces with opportunities to exit level geometry or feel as though they'd broken the game.

Figure 3: The performance spaces in Soundscape.social's second concert

3.3 Soundscape.social: The Follow-Up

The second iteration of Soundscape.social included a classical guitarist set in a snowy forest, an avant-garde arrangement for flute and upright bass in the sky, a jazz duo in a sci-fi cityscape, and a violinist and flutist in an Asian street setting, as shown in Figure 3. All four environments featured interactive elements, such as light-able lanterns and pickable flowers that players could throw at performers. Two spaces modify movement mechanics themselves: participants enter the cityscape by riding a motorcycle through a tunnel, and players

appear to others as animated birds in the sky, corresponding with increased movement speeds and lessened gravity.

The new chat function revealed a novel communication procedure. Communication was both universal, in that text would appear in everyone's display regardless of player location, and local, in that the text would be placed as a note in the author's location. This meant that users would often have conversations with others who were nowhere near them at the time of sending, and the conversation would be spatially separated in their long-term storage.

We adjusted our design of Soundscape.social for its third concert:

- The third iteration was playable in web browser in hopes of increased attendance.
- Inspired both by positive reception to the sky navigation and need to reduce labor, the next iteration primarily focused its novel interactions around spatial navigation.

Figure 4: The introduction and performance spaces in Soundscape.social's third concert, an homage to the works of David Lynch

3.4 Soundscape.social: An Evening at Club Silencio

In Soundscape.social's third concert (subtitled "An Evening at Club Silencio," an homage to David Lynch), a jazz trio played in a waiting room inspired by *Twin Peaks* (Figure 4, upper-right) and music from a piano and tenor appeared in an apartment space from *Rabbits* (bottom-middle); both spaces featured illusions of infinite hallways, disorienting players in space. Avant-garde toy piano pieces were featured in a clinic scene inspired by the apartment building from *Eraserhead* (bottom-right), which also included a hallway that would shrink players' avatars, allowing them to explore the spaces as the equivalent of a couple inches tall. A fiddler played from a tractor as a nod to the film *The Straight Story* (bottom-left), featuring an infinitely scrolling street surrounding the player, giving the illusion of movement. This space features a hidden area containing a representation of a Musicircus: performers from all other spaces of this concert are arranged on top of each other. In addition to performance spaces, this concert features a "prologue" space, spawning players in a parking lot outside *Mulholland Drive*'s Club Silencio (upper-left).

4. Evaluating the Concert Series

We carried out a series of semi-structured interviews with 9 attendees and 2 musicians according to our IRB-approved protocol. Most interviewees attended at least one opening night, which afforded the most opportunities for contemporaneous socializing. The majority of the 9 attendees interviewed (6/9) were graduate students, all but one studying subjects not explicitly related to technology and none studying music. All the attendees claimed to be regular attendees of concerts prior to the pandemic, one claiming to exclusively attend classical music performances, four claiming to only attend concerts of other genres such as rock or pop, and four claiming to attend both. Aside from the one student studying Information Science, none of the interviewees considered themselves technology experts.

Table 1: Summary of basic quantitative participation information from Soundscape.social's concerts. "Launch Users" indicates the number of unique users present within the first two hours of launch, "Total Users" indicates the number of unique users who attended the concert in total, "> 0 Notes" indicates the number of users who wrote at least one note using the in-game system, and "Median Notes" indicates the median number of notes send by any unique user for the entire concert

	Launch Users	Total Users	> 0 Notes	Median Notes
Opening Night	25	48	29	2
Follow-Up	17	17	24	2
Club Silencio	13	13	12	0

4.1 "Did you find that the relationship between musicians and audience members was different in Soundscape.social than a typical concert?"

Interviewees drew attention to the fact performers were not performing in real-time, which made the interaction feel less personal. Some were disappointed by the vagueness of performers' visual representations, as the instrument avatars gave no opportunity for attendees to observe the performers' skills. Others seemingly contradicted this perspective, claiming Soundscape.social allowed them a "more personal" connection to the performer, as they had greater spatial control over their own listening experience and (through notes) were allowed to contribute to the performance itself in a way they found impactful. This audience recognized themselves as participants, also performing.

4.2 "Was Your Relationship to Other Audience Members Different?"

Nearly every attendee mentioned Soundscape.social's lack of social obligation and cause for social anxiety that would otherwise stem from other attendees' judgments and physical interactions in in-person spaces. Though all interviewees mentioned fears that anonymity would cause toxic behaviour, their experienced reality reflected an alternative view of anonymity that allowed for a "wholesome" demeanour.

Interviewees experienced a sense of temporal spatial proximity to other attendees as they witnessed each other's avatars move through the performance spaces with theirs. Communication through notes, however, was unsatisfying to most interviewees in that it did not feel "real-time" enough. In this way, we may expect to dismiss the notes function as failing to provide temporal liveness. However, in discussing the notes feature with interviewees who attended Soundscape.social outside of its launches, who viewed the notes exclusively as interactive "graffiti," we see the opposite. Though notes serve as a purely historical record of past conversations, they are revealed to attendees contemporaneously to their own navigation of a community's opinions of the experience as it is happening to them: a kind of access to audience opinions unheard of in a conventional live performance. In this instance, live temporality is not a simultaneously contemporaneous phenomenon for every participant but alternatively, a purely subjective phenomenon: a conversation happening right now, but only from this player's perspective.

4.3 "Do you Think There Will Still be a Need for Experiences Like Soundscape.social After the Pandemic?"

Interviewees had two primary justifications for the continued existence of virtual concert experiences outside of a global pandemic: accessibility and convenience, both due to the fact virtual concerts require no navigation of public (physical) spaces. A musician we interviewed was excited for the chance to be an audience member at her own concert, not a possibility for in-person concerts. She described this as being almost like being a visual artist allowed to be in the gallery exhibition space of their own work yet acting as spectator.

5. Discussion

In creating Soundscape.social, we've demonstrated the feasibility of using existing technologies, including Unity, Photon, Flask, and Itch.io, to create virtual worlds inexpensively and quickly with small teams. In the context of John Cage's method of embodied politics in music performance, we theorize that the same method applies to virtual worlds. Every virtual world models how human beings organize ourselves, and by encouraging greater innovation within the Paraverse, we not only expand the cultural imagination of the Metaverse but the cultural imagination of our corporeal human societies.

Soundscape.social manifested an ongoing, collaborative construction of liveness as opposed to a finite event, as most clearly shown in its communication format. This lends to the establishment of a "sense of unity" by

sharing information on audience reactions to a given performance, creating an element of liveness even when reading notes long after they have been written. The spatialized nature of the audio in Soundscape.social contributed significantly to the experience of liveness. The spatialized audio allowed players to transcend the musician/audience member binary, as each member composes the music, manipulating the dynamics and the type of music they are hearing, by moving around the space.

Soundscape.social, like the Musicircus that inspired it, created a unique musical model of anarchy, both in the format of listener-centric experiences themselves, and in the maintenance of gracious anonymous interpersonal communication and interaction without punishment structures. We extend these egalitarian politics into our method of iterative design. Most of the design insight for iteration came from the observed placement and content of anonymous notes. This method respected privacy not only in that it collected no personal information, but in that it based design insight on data players had chosen to broadcast to the community.

6. Conclusion

We theorize the concept of the Paraverse, the global set of disconnected virtual worlds and virtual world platforms working in parallel to develop virtual world technologies and culture. Through the design and implementation of our system, Soundscape.social, we demonstrate how small teams of independent developers may quickly contribute to the fringes of the Paraverse, and thus play an essential role in driving innovation of the form.

From evaluation of our system, we expanded on prior work on the concept of "Liveness." We sought to expand the notion of liveness through listener agency in temporal, exclusive, spatial, and interactional ways. We came to conceive of liveness as actively co-constructed in spatiotemporally, as a participatory experience contingent on listener agency.

We emphasized individual autonomy of audience members and challenged hierarchical structures of listening. This returns us to Cage's suggestion that "by making musical [performance] situations which are analogous to desirable social circumstances which we do not yet have, we make music suggestive and relevant to the serious questions which face Mankind" (Cage 1979). Through a listener-centric concert experience, we explore possibilities for virtual worlds that serve as models, however modest, for egalitarian politics and the possibility of further explorations throughout the Paraverse.

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Unpacking Student Perceptions of Board Game Mechanics

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Abstract: The boardroom challenge is a custom developed board game used as a formative assessment in an undergraduate business management course. The course forms part of an Accountancy degree which culminates in the professional designation of members to the South African Institute of Chartered Accountants (SAICA). Students are required to develop skills and competencies towards future membership of their professions professional body. To this end an industry employer and training company partnered with the University to develop students' business acumen utilizing gamified learning in the form of a custom developed board game. The boardroom challenge has taken place annually from 2015-2019 and commenced again in 2022 when Covid-19 regulations permitted. On game day students compete in randomly assigned groups of six with an industry game master at each table as a facilitator. Students and facilitators complete questionnaires after the boardroom challenge providing feedback and suggestions. Open ended feedback from 2015-2019 has been thematically analysed to evaluate perceptions on game mechanics. Game mechanics include rolling the dice to determine which scenario students need to address. During the game students have to answer theory questions or address scenarios, depending on what the dice causes their game piece to land on. Correct answers earn currency in the game and students display their new rank in the organisation with each correct answer. Moving up the salary scale tops out at CEO after which students can begin to earn shares. Turn taking is regulated by a timer, to ensure everyone has sufficient turns while industry based game masters make the final call on the appropriateness of answers to open ended scenario type questions. The board game generates great excitement and engagement from students with several preparatory activities scaffolded into tutorials before game day. Students' perception of the various game elements and mechanics indicate their evaluation is dependent on how they have conceptualized the impact of specific mechanics on their marks. As a mitigating factor, the data was gathered and analysed over many years.

Keywords: Game based learning, Gamification, Board games, Serious games, Management education, Game mechanics

1. Introduction

The focus of this article is a bespoke board game, this serious game was developed as a partnership between the University, an industry partner, and a consultancy company. The purpose of the board game, which is known as the boardroom challenge, is to function as a tool for instruction and assessment that develops students' business acumen. The boardroom challenge takes place once a year when all the enrolled students (between 350 to 550) participate, sitting six at a table with an industry expert game master. The students participate individually in the challenge, after a round of quick fire questions the winner picks the industry they will represent throughout the game. Next students conceptualise a company name and business card and they have to address the questions that arise throughout game play from the perspective of their company in the selected industry. Students roll the dice and have to respond to theory questions or contextual scenarios in the form of risk, enabler and world event cards. Their primary aim is to progress from accounting clerks to the CEO's of their companies, earning game cash with each correct answer and progressing to earning shares, whilst risking demotions and losing cash for wrong answers. As time has gone by iterative changes have been made to the board game rules as well as to the preparatory activities for students and training for game masters. In this article game mechanics as well as the development of serious games will be discussed in the literature review. An overview of the board games mechanics and their development as well as students perceptions of these mechanics follows, culminating in a discussion of insights gained and areas for future research.

2. Background

The undergraduate students that participate in the boardroom challenge are working towards a chartered accountancy qualification and ultimately membership of the renowned industry association, the South African Institute of Chartered Accountants (SAICA). The learning outcomes that students need to achieve in order to attain membership are well articulated and require members to be technically proficient ethical, critical thinkers (SAICA, 2019). The course in which the boardroom challenge takes place is an undergraduate business management module and in addition to module specific learning outcomes, students need to develop an understanding of the complex and multidimensional world of business that they are preparing to enter. The SAICA competency framework emphasized that as future chartered accountants they should have "business and entrepreneurial skills which make effective responsible leadership in the business context possible". The board game qualifies as a serious game due to the learning outcomes that students are intended to achieve

through their participation. The board game aims to play a role in developing the requisite skills which are also more broadly addressed by additional instructional initiatives in the course, including preparatory activities to support student readiness to engage proactively in the board game.

Figure 1: The business card where each student designs their company logo and records their performance

The board game was first developed and played in 2014, the authors involvement in facilitating and helping to evolve the board game started in 2015. From 2015 to 2019 the boardroom challenge took place annually, in person teaching was disrupted in 2020 and 2021 due to the Covid-19 pandemic and luckily the challenge could commence in person again in 2022. Student and game master feedback was solicited annually to inform updates and improvements for subsequent iterations. This article will focus on student perceptions of gameplay as they relate to mechanics. Part of the value of having a clear definition for game mechanics is so that it can be productively used to analyse games (Sicart, 2008), however the definition is also needed to productively inform game design. Consequently, the primary and secondary mechanics and their evolution merits investigation.

3. Problem Statement and Research Question

One of the primary purposes of developing and annually hosting the boardroom challenge is to develop undergraduate students' business acumen. A gamified approach was selected and the resultant board game is an experiential learning activity as well as an assessment. Based on annual student and facilitator feedback the matters that students raise as suggestions for improvement are focused on what they perceive will improve or optimize their grades. As students indicate they have had limited previous exposure to board games and gamified learning assessments their consequent concerns are with rule changes they perceive as beneficial. Adopting student suggestions influences game mechanics and presents an interesting dynamic to the game designers and facilitators. Students comment on what they experience and would like remedied, and the board game designers must conceptualise changes and updates with regard to operational considerations, such as the training of game masters and how much uniformity of play should be introduced relative to the desired customized learning experience. As a result, this article intends to;

Explore a board games mechanics, through the lens of student perceptions.

4. Review of the Literature

Games can be thought of as systems which include game mechanics, rules and challenges, in the course of playing the players develop agency and can also behave in unpredictable ways (Sicart, 2008). The literature review will discuss the definition of serious games and how players learn in the context of these games and conclude with a discussion on game mechanics.

4.1 Serious Games

At first glance the term serious games seems to be an oxymoron, but historical evidence supports the use of games for learning as an established idea (Ma, Oikonomou and Jain, 2011). One of the first definitions of serious games comes from Abt (1970) who describes serious games as having an explicit educational purpose and therefor the game is not primarily played for the purpose of enjoyment. According to Ma, Oikonomou and Jain (2011: p.45), "games are extraordinary learning tools and motivate players to explore the edges of their competence, their skills, and their knowledge". Consequently, the idea of learning in the context of games can be referred to as serious learning, finding its theoretical roots in the theory of transformative learning. Games create a possibility space, which not only sets the scene for transformative learning, but also encourages the development of agency and growing competence as players engage with the serious game.

While there is evidence that learning can take place during gameplay, the questions of what and how players learn through gameplay and the issue of pedagogical effectiveness has room for empirical support (Gee and Hayes, 2010; Ma, Oikonomou and Jain, 2011). Bateson (1972) describes learning as a relational phenomenon with logical levels. The levels of learning identified by Bateson (1972) were reconceptualised by Ma, Oikonomou and Jain (2011);

- Learning ***in*** serious games – involves linear interactions where players collect information about how the game works and then act and memorize.
- Learning ***through*** serious games – involves 'framing' and attributing meaning by interpreting the information gathered, in this context decisions are made between alternatives.
- Learning ***beyond*** serious games – this refers to an important aspect of serious learning where what is learnt in and through the game are transferred, transforming the players approach to future problems.

With regards to the evaluation of whether serious games helped learners achieve learning outcomes, O'Neil, Wainess and Baker (2005) concluded that the pedagogical effect of games was insufficient when not supported by educational instruction. In other words, instructional strategies that support learning outside the game, support learning in and through the game and especially beyond the game (Ma, Oikonomou and Jain, 2011).

4.2 Game Mechanics

Game Mechanics connects the actions of players to the purpose, and main challenges of the game. Game mechanics guide players interaction with the game world created during play (Sicart, 2008). Rouse (2005, p. 310) describes game mechanics as "what the players are able to do in the game world, how they do it, and how that leads to a compelling game experience". Cook (2006) explains that game mechanics are the system based on rules that enable a player to both explore and learn what is possible in the game by understanding the game properties though the games feedback measures. Järniven (2008, p. 254) relates game mechanics to player agency, taking experiences of gameplay into consideration, meaning mechanics "guide the player into particular behaviour by constraining the space of possible plans to attain goals". A further clarification comes from Juul (2005) who states that game designers need to create the mechanics that are used to interact with the game, which ultimately modify the game state. In this view, game mechanics are often designed to overcome challenges that can occur in the game state. A game specifies certain core challenges that players need to overcome and then the game designers have to create game mechanics that players can use to overcome these challenges (Sicart, 2008). Game mechanics interrelate and it is also important to consider the effect of game mechanics on players' experiences and emotions.

In some cases no distinction is made between game mechanics and game rules (Lundgren & Bjork, 2003). However, Avedon (1971) and Sicart, (2008) distinguish between game mechanics and rules. The rules of the game create possibilities for players regarding their interactions with the game. Games that use algorithms are in fact relating the rules of the game with game mechanics which result in game state changes as a result of the rules being applied (Sicart, 2008). In this description rules and mechanics can be observed to be related but distinct aspects of game design.

Games can have primary (core/central) and secondary mechanics and it can be valuable to distinguish them (Sicart, 2008). Primary mechanics help players to overcome central challenges in the game in order to achieve the primary goals of the game, whereas secondary mechanics influence player experiences and can add to the flow of gameplay but do not necessarily relate to core game challenges. Another interesting perspective is that of contextual mechanics. A game can be designed to map multiple mechanics to one action by players (Järvinen, 2008). By design games have desired end states that players are focusing their actions and agency on achieving and there are a set of core mechanics which are directed at supporting players achievement of the desired goals (Sicart, 2008) .

5. Methodology Utilised

Data was collected from 2015 to 2019, unfortunately, Covid-19 caused all assessments to move online for 2020 and 2021. The Boardroom challenge was held in person again in 2022 and data collection is set to resume in 2023 at the annual Boardroom challenge. A thematic analysis was conducted on the open ended question posed to students; "Do you have any other comments about 'the Boardroom Challenge' that you would like to

make?" The data included the researchers' reflective diary, including meeting notes and reflections about game changes, as well as rules and training material as additional data points.

5.1 Data analysis

The discussion of boardroom mechanics is based on document analysis, using the reflective diary, rules, annual changes and updates and training material for game masters and students as data. Student perceptions about game mechanics have been analysed using a thematic analysis, as outlined by Braun and Clarke (2006); the first phase involves becoming familiar with the data, in the second phase initial codes are created. The next step involves refocusing the analysis at the level of themes and then proceeds to refining the themes that have been identified. Once themes have been crystallised they need to be defined and named, followed by the final step of reporting on the results.

6. Findings and Discussion

The first part of this section will discuss the mechanics of the boardroom challenge taken from the documentary analysis, after which the thematic analysis of student perceptions will be presented.

Figure 2: The Boardroom Challenge board

6.1 A Closer Look at Mechanics – the Flow of the Game

The Boardroom challenge does prescribe goals, such as climbing the corporate ladder, from accounting clerk to CEO. As such player actions and the strategies they conceive within the boundaries of the rules are designed to achieve a higher job status in the game, ultimately earning shares once they have reached CEO status and earning game cash.

Mechanics involve player agency and how players interact with the game itself. As set out in the literature review, mechanics are designed to help players overcome challenges in the game and achieve desirable game outcomes. Accordingly, the **core mechanics** of the boardroom challenge relate to reaching the highest organisational position and earning game cash;

- Players can be promoted to higher levels
    - This mechanic relates to the analogy of climbing the corporate ladder. Players all begin as accounting clerks and through correct answers to risk, enabler and world event cards can increase their rank in the organisation (figure 3). Each organisational rank represents a salary level, which is factored into students' final score. Players cannot be promoted beyond CEO and correct answers after that final promotion enables them to earn shares. Players can also avoid being demoted by answering theory cards correctly.
- Points are awarded by way of game cash earned
    - Correct answers to risk, world event and enabler cards attract instant cash (alongside promotions) in the game. Incorrect answers to risk, world event and enabler cards result in forfeiting game cash. Correct answers to theory cards only earn or lose cash, not resulting in promotions.

The core mechanics stated above are also examples of contextual dynamics identified by Järvinen (2008), because a correct answer achieves both a promotion and earning game cash which help players achieve the ultimate goal of the game.

There are other elements to a game that also influence players interaction with the game state but are more accurately described as secondary mechanics (Sicart, 2008). These mechanics could be described by the rules of the game, although they are not synonymous with rules. Examples of secondary mechanics that are relevant for the flow of the game are;

- **A true and false quiz** to determine who picks their industry and rolls the dice first.
- **Designing business cards** (figure 1), to help students immerse themselves in the game by naming their company and outlining their core business. This allows students to contextualize their game play, for example if they choose the automotive industry, they can choose to be an electric vehicle manufacturer or a manufacturer of component parts, however all subsequent questions have to be answered from that vantage point.
- **Leaderboards** – around each table, each player has a card holder which displays their "chair rank" and organisational level to co-players
- **Reward systems** – In 2016 shares were added to the game for students to earn after reaching CEO status. Earning shares have an important impact on game day performance and grades as students have then achieved the primary goal of the game.
- **Loss aversion** – An update in 2017 meant that students can also avoid demotions after incorrect answers to risk, world event and enabler cards by correctly answering a theory question.
    - **Timers** – Another early frustration for students were untimed lengthy answers which slowed the progress of all players at a table. Facilitators also took their mentorship role seriously and gave plenty of feedback to answers, unintentionally slowing down players' and negatively affecting their marks. However, most students were unwilling to say anything to the game master as an older person with industry experience whom they did not want to offend. Thus the timing had to be communicated to students and formalized in the game master training to eliminate unintentional consequences and power dynamics. The use of timers was primarily instituted to ensure a game pace that optimized everyone's opportunity to increase their chair ranking and cash earned by having more turns.
- **Feedback systems** – In addition to displaying their chair ranking, there are also announcements on the day and small prizes awarded to the first students who achieve CEO status.
    - Customized feedback also comes from game masters at each table having the final say in whether an answer is correct and explaining why an answer may fall short and what students would need to address in order to 'get it right' next time. Not only is this an example of mentoring, it also plays a role in learning ***through*** and ***beyond*** the game (Ma, Oikonomou and Jain, 2011).
- **Lucky break cards** – the first two students that land on the pot of gold icons can receive lucky break cards. These cards provide immunity which students can use if they don't know the answer and want to avoid demotion. An interesting example of students using mechanics in unintended ways emerged as certain students held on to their lucky break cards hoping that they will count for marks (an unspecified outcome), instead of using those cards to avoid demotions or losing game cash (which students knew would result in lower marks).
- **Game masters** – employees of the industry company are game masters on the day, fulfilling a mentoring role and contributing towards the corporate social responsibility of their company. Originally one game master oversaw three to five tables, just checking in and advising. This left it up to students to decide if answers provided by their peers were accurate. Some students seemed to think that they need to "hold back" other players at their table in order to do well and sabotaged them by saying their answers were incorrect. To mitigate this risk, each table had a game master allocated who stayed with their table as the arbiter of whether answers are correct. Within the allocated time they could ask questions, giving students the opportunity to expand on their answer. If the answer was incorrect they could explain afterwards what elements students need to consider to get future answers correct. The explanation of the board game was also adapted to emphasize to students that they are each running their own race as hopeful CEO's of their respective industries.
- **Top ten gameshow quiz** – a formula is used to identify the top ten students on the day. Shares and cash are the two components that have a multiplier effect on student results in order to identify who makes the leader board. The top ten participate in a gameshow like quiz where the ultimate winner is the student who answers the most multiple choice theory questions correctly. Students final course marks are calculated using a slightly different formula which weighs the elements they have the most

control over highly and benchmarks their performance to the average performance at their assigned table (to take contextual elements of gameplay into consideration).

Figure 3: The types of cards students receive in the game

6.2 Thematic Analysis

The codes over the years of data collection were aggregated into three themes which can be seen as different ways of experiencing the board games mechanics. The themes are presented visually in figure 4 and could be considered an evolution of student perspectives, from being caught in the minutae to focusing on the bigger picture, although admittedly not all students expressed all these sentiments.

Theme 1: When luck is on your side…or not

The board game board contains the icons displayed in figure 3 and a roll of the dice determines the scenarios students have to address during their gameplay as they pursue promotions and earning game cash. A consistent aspect of feedback over the years relates to experiences of luck being an unfair dimension of the game, having a limiting effect on their marks. Some sentiments relate to the gamified equivalent of the student adage, "I knew all the answers, you asked all the wrong questions". Examples typifying student sentiments follow;

> *2015_8 "I don't think its correct to test a persons' knowledge by the role of a dice because some cards had more money earnings than others"*

> *2015_13 "It should not count for marks as this is an unfair way of testing whether a student understands and remembers the work"*

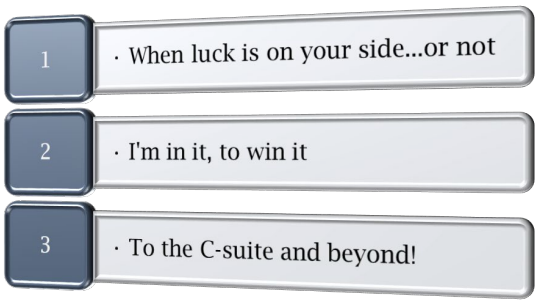

Figure 4: Overarching themes

> *2015_36 "(I) felt the boardroom game was not really fair on me as my success was dependent on the people in my group whom in my opinion (I) felt they were very selfish"*

2017_38 "It would be much more fair if the whole game was based on theory only, because not everyone has the ability to think under pressure and provide logical answers about world event, enabler and risk questions in just 1 minute. Hence I feel the mark received I will not be a true reflection of my knowledge"

2017_52 "The facilitator was too observant. People crashed my points in order for them to win."

2019_19 "I feel that the game should not be based on the luck of where you land or constrained by time in order to get to the top 10"

2019_58 "Some people ask follow up questions so that they can only crush you and not that they would really like to know the response."

In 2015 the most feedback was received about unfairness. Iterative improvements are made every year and the frequency of these concerns have decreased as a result of game master training updates, and rule changes as well as adjusting the weighting of different components as they relate to student marks.

Theme 2: I'm in it, to win it

While theme one comments aligned more with an extrinsic locus of control, another category of student feedback revealed a different perspective, highlighting student agency. While students still highlighted aspects of concern, they were more focused on providing suggestions for improvement. Some suggestions showed that students had moved beyond the abstract game experience to think about how certain mechanics function and how they could be 'fixed', aligning with Ma, Oikonomou and Jain's (2011) phase of learning *through* serious games;

2015_2 "It was really a fun day, maybe the instructions can rather be made into an instruction video with a basic or small demonstration on how to play the game instead of having the facilitators explain the rules and how the game works."

2015_14 "Please include a TIME LIMIT to questions because one's success ultimately relied on how many opportunities one had to gain money."

2015_15 "I think the facilitator should have the say on the whether the answer is correct or not. The reason for this is because the people in the group may be more lenient or more critical than others, therefore disadvantaging them."

2015_22 "I would suggest, that the risk, enabler and world events have a few bullet points as guidelines for answerers and that a time limit is set for each answer."

2017_138 "I think it should be stressed enough that people should study for it and people should be t(au)ght how to think when faced with the challenges in the game one lecture before and after the game"

2018_21 "It would be much more interesting and very easy for other students to earn more points if they can volunteer to answer the question of others if they are unable to answer."

Theme two started to reveal students' awareness of game dynamics and the positive tone of their suggestions that would benefit their peers in future intakes.

Theme 3: To the C-suite and beyond!

Students clearly had different levels of awareness about game mechanics. Many students were 'in the moment' focusing on what Ma, Oikonomou and Jain, (2011) describe as learning *in* and eventually *through* serious games. However, some student feedback revealed reflections about lessons learnt through the game and their potential future relevance, referencing learning *beyond* the serious game and hopefully sentiments showcasing transformational learning;

2015_20 "The board game made me realise how valuable the theory we learn in class is in the organisation and changed the way (I) viewed commerce completely. (I) now understand its importance and will try to understand more than learn the information for an exam situation."

2017_21 "What made playing the game a great learning experience is the fact that whenever an answer was not adequate, afterwards our facilitator would explain to us how she would've solved the

particular scenario and the contributing factors she would've considered in real life. This made the experience a lot more fruitful."

2017_87 "The game created a very big difference in how i think and made me realise how important it is to fix my attitude towards life."

2017_161 "It taught me the importance of being broad minded and how to face my opponents even though I felt intimidated by them."

2018_35 "The boardroom challenge help me to communicate with people I never talked to and it taught me that in the outside world communication is a main source to help someone who is a businessman or business woman solve complex problems."

2019_30 "It was a great learning experience. It forced me to think out of the box, as well as forced me out of my comfort zone, which is something I really liked."

7. Ethical Considerations

Ethical clearance was granted by the University. While all students were asked to provide feedback, only students who consented to their responses being analysed form part of the sample and their feedback was anonymized. A link to the questionnaire was hosted on the learning management site and students could respond at their own convenience and were not compelled to provide feedback.

8. Limitations

The questionnaires that students and game masters completed are subject to self-reporting bias. Students with strong opinions about their experience and consequently the influence of the Boardroom challenge on their marks were most likely to complete the questionnaire. This implication is mitigated by the feedback being collected from cohorts across multiple years and the researchers' reflective diary as an additional data point, providing another source of data triangulation.

9. Suggestions for Future Research

Measuring learning ***beyond*** the board game can lead to deeper insights into how to better prepare students for the world of work and the extent of transformational learning that has taken place. A focus group with game masters who participated in the game as students and are now working with the industry employer, could also provide insights into the extent of transformational learning.

10. Conclusion

Gathering and incorporating annual suggestions for improvement provide an interesting lens for how game mechanics are experienced. Interestingly, in student feedback the different phases of learning ***in, through*** and ***beyond*** serious games could be identified. More reflective feedback by students, exemplified in theme two, also made suggestions for game improvements, revealing development of student agency. Analysing game mechanics through the lens of core, secondary and contextual mechanics was also revealing, as the core and contextual mechanics clearly related to the primary challenge of the board game, climbing the corporate ladder.

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Need-Based Game Design: Developing a CT Game Based on Educational Needs

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Abstract: According to reports and previous research, present and future society show a high need for citizens with technical skills, such as computer programming. The need for technical competent citizens can however be challenging for higher education institutions to accommodate due to low numbers of students in higher education computer science. But also due to the high drop-out rates and low pass rates in introductory programming courses. With that said, it is important to both recruit new students to computer science and to support those who already study the subject, to meet the demands of the present and the future. An approach that has shown great promise in motivating students while still keeping focus on the learning aspects in education, is game-based learning (GBL). To facilitate support in higher education computer science, more specifically courses in fundamental programming, this study had the aim of identifying important design concepts in the development of a need-based educational game on computational thinking (CT). Skills related to programming have commonly been organized as part of the CT concept. To identify the educational needs, e-mail interviews were conducted with teachers that teach higher education courses on computer programming in Swedish universities. Based in an on-going design science project to create a learning game on computational thinking for higher education, the study discusses and compare the identified needs with design theories, such as affordances, emotional design, and sustainable design. The conclusion is a conceptual design of the educational game with a set of recommendations for a need-based game design in educational context.

Keywords: Educational game design, Design science, Design theory, Need-based design, Computational thinking

1. Introduction

Reports and previous research indicate that technical skills and computer programming will be important in both present and future societies (Smit et al., 2020; Wolz, Bergande & Brune, 2022). As digitalization continues to advance and new technologies such as AI have a greater impact, the demand for such skills will escalate (Gulliksen et al., 2020; Johnson et al., 2021). However, higher education institutions face challenges in meeting the demand for technically competent citizens. Factors such as low enrolment numbers in computer science (CS) programs and high dropout rates contribute to this problem (Hawlitschek et al., 2020). Previous research also highlights the potential problem for learning programming if there is a lack of understanding during the initial contact with programming (Shuhidan, Hamilton & D'souza, 2009; Cheah, 2020).

Many CS programs globally start with an introductory programming course. The outcomes of such courses can be disappointing, as students tend to struggle with grasping fundamental programming concepts, procedures, and processes (Bennedsen & Caspersen, 2007; Cheah, 2020). This challenge has been addressed in prior research, such as Gorson and O'Rourke (2020). According to Rahman, Anuar and Said (2018) and Settle, Vihavainen and Sorva (2014), a possible factor for students dropping out of programming courses in later stages of their studies is a lack of motivation during the early stages. Given these challenges, it is crucial to not only attract new students to the field of computer science but also provide support and motivation to those who are already studying the subject. This is essential in order to meet the demands of present and future workforce.

Game-based learning (GBL) has emerged as a promising approach that effectively motivates students while simultaneously maintaining focus on learning (Klopfer, Osterweil & Salen, 2009; Humble, Mozelius & Sällvin, 2021; Humble, N., & Mozelius, P., 2022). Previous research has also shown promising results regarding students' engagement and attitudes towards computer programming when using GBL (Papadakis & Kalogiannakis, 2019). This study is part of a project aimed at developing an educational game that teaches fundamental programming in higher education, with a focus on Computational Thinking (CT). The aim of the study was to identify important design concepts in the development of a need-based educational game on computational thinking (CT). The research question to answer was:

RQ1. What are important design concepts in development of need-based educational games on computational thinking?

2. Theoretical Background

It should be noted that there is no absolute consensus on what constitutes design theory, but rather there are some characteristics of design theory that are more shared than others (Baskerville & Pries-Heje 2010). For example, design theory is often considered prescriptive, explaining how design should be conducted to improve, make more efficient and so forth (Walls, Widmeyer & El Sawy, 1992; March & Smith, 1995). The practical nature of design theory is often highlighted, for example, that "Design theories are considered as theorized practical knowledge" (Goldkuhl, 2004). For the design of the artefact, this study focuses on three specific theories for design (affordances, emotional design, and sustainable design) which are further described in subheadings below.

2.1 Affordances

James Gibson coined and developed the theory of affordances (Bower & Sturman, 2015; Stendal, Thapa & Lanamäki, 2016), which has commonly been defined as the action possibilities that the environment provides (Gibson, 2015; Bower & Sturman, 2015). Donald Norman later introduced the theory to Human-Computer Interaction (HCI) and further developed it to apply in research and design of artefact (Stendal, Thapa & Lanamäki, 2016). Norman (1999) specified the concept of affordances to also include perceived affordances, constraints, and conceptual models. According to Norman (2008), affordances as intended by Gibson did not have to be perceived by a user. However, since this is a crucial aspect in the design, Norman (1999) introduced the concept to the theory. Norman also frequently mentions two other concepts related to affordances: constraints and conceptual models. Constraints inform the user of which actions are not possible to perform with an artefact, these are often based on physical, logical, or cultural constraints (Norman, 1999). Norman (1999) have stated that conceptual models are the most important aspects of design, since these underly all other parts of design and are what everything else should be consistent with. A conceptual model can be understood as an explanation of how an artefact works, a simplified and useful description (Norman, 2013).

2.2 Emotional Design

According to Ho and Siu (2012), emotions and design are mainly being combined from the 1990s, while design previously (from the 1950s) focused primarily on the functionality of artefacts. In the HCI field, Norman's model for emotional design is often considered one of the more influential (Adelson, 2010; Preece, Sharp & Rogers, 2015; Pengnate & Sarathy, 2017). Norman (2005) divides design into three levels that are processed by humans when interacting with an artefact, which together form a holistic experience: visceral, behavioral, and reflective. The initial impact or appearance of an artefact is referred to in the visceral design (Norman, 2005). The visceral design could also be said to classify the artefact's attractiveness (Noman, 2005). The look and feel of an artefact, or the experience in total, is referred to in the behavioral design (Norman, 2005). It could also be said that the behavioral design is about classifying the artefacts regarding to their functionality and usability (Norman, 2005). Lastly, the thoughts and feelings afterwards, or the image and message left on the user, is referred to in the reflective design (Norman, 2005). The reflective design could also be said to classify the degree of prestige associated with an artefact (Norman, 2005).

2.3 Sustainable Design

Sustainable development emerged as a concept with pressing concerns for scarcity of resources in the 1960s (Carson, 1962; Hardin, 1968; Baldassarre et al., 2020). Sustainability is often understood as a collection of different types of sustainability, such as environmental, social, and economic (Mota et al., 2015). Combining and balancing these different aspects of sustainability has proven to be a challenge in, for example, production, consumption, and supply chain management (Mota et al., 2015; Azapagic et al., 2016). In the field of HCI, sustainability is addressed in, for example, Sustainable Interaction Design (SID) (Blevis, 2007). Blevis (2007) presents SID as a general framework for describing sustainability in relation to design values, design methods, and design reasoning. According to Blevis (2007), SID provides a discourse for reflecting on sustainability as a design value and relating sustainability to other design values. As a method for design, SID incorporates the idea to be mindful of the effects that interaction design can have on environmental sustainability and on behaviors that in turn effect environmental sustainability (Blevis, 2007). Lastly, SID can also be used for reasoning on the accountability of interaction design for sustainability, in terms of, for example, disposal, recycling, sharing, use and re-use (Blevis, 2007).

3. Method

This study is part of an on-going design science project with the purpose of creating a learning game on computational thinking for higher education. The design science process outlined by Johannesson and Perjons (2014), containing five phases, have been used for this project. The five phases are:

1. Explicate problem
2. Define requirements
3. Design and develop artefact
4. Demonstrate artefact
5. Evaluate artefact

The first phase, Explicating the problem, was carried out and described in a previous study (Mozelius, Sällvin & Humble, 2023) and in the introduction section of this paper. The focus for this study is on phase 2 and phase 3 of the design science process. To define the requirements (phase 2) and outline the design and development of the artefact (phase 3), this study has collected data through structured e-mail interviews with higher education teachers (further described in 3.1 Data collection) and compared the results to design theories (further described in 2. Theoretical background) in the discussion section of this paper. The conclusion of this paper is a conceptual design-model for a need-based game design, based on the findings from this study. This conceptual design-model will guide the continuing development of the artefact, which will be demonstrated (phase 4) and evaluated (phase 5) in a future study.

3.1 Data Collection

Structured e-mail interviews were sent to 18 teachers that teach higher education courses on computer programming at three different Swedish universities. The 15 interviews that so far has been answered have been used to define the requirements for the educational game. This is a continuation and extension of the preliminary requirement definition that was carried out in a prior study (Mozelius, Sällvin & Humble, 2023), a study that built on an analysis of the first 6 answered interviews. All interviews have been conducted with the same questionnaire with open-ended questions, and with the principle of keeping all informants as anonymous as possible during the research process. Informants have been selected according to the idea of a purposive expert sampling (Etikan, Musa & Alkassim, 2016), where all the interviewed teachers have a long and rich experience of introductory programming courses in higher education.

3.2 Data Analysis

In the first analysis, one of the investigators carried out a separate analysis of six interviews according to the open coding method as outlined by Khandkar (2009). In the open coding phase, interview data were read, reread, and colour coded to identify data extracts, codes, and potential categories. The second analysis phase used the Grounded theory idea of axial coding that has been described as: "coding that treats a category as an axis around which the analyst delineates relationships and specifies the dimensions of the category" (Bryant & Charmaz, 2007, p. 603). Moreover, the data were reassembled into more abstract conceptual categories in the axial coding with potential relationships between the categories. The focus in axial coding is often put on one central category (the phenomenon), with its relations to the other categories. Independent on the studied phenomena, there are always relations and interactions between the central phenomena and other categories (Vollstedt & Rezat, 2019).

In the axial coding process in this paper, data were organized around two central categories: 'Imperative Programming' and 'Object-Oriented Programming'. These two categories were chosen because they were central in the collected data, mentioned by several of the participating higher education teachers, and highlights aspect of what could be considered important for the game design (relates to the study's aim and research question). Imperative programming is often the programming paradigm that students are introduced to and could be described as a way of writing code where the control flow of the program is defined (Corral et al., 2014). Object-oriented programming (OOP) on the other hand, is a programming paradigm that encourages the programmer to think about the code in terms of objects with properties and behaviours, much like in the real world (Corral et al., 2014). These

4. Results

Result from the analysis is presented in sub-headings below. As described in the data analysis-section, findings have been organized around two central categories: 'Imperative Programming' and 'Object-Oriented

Programming'. However, the categories addressed around each central category are not necessarily exclusive, but rather represent the context and relationship expressed by the study participants. Quotes from the participants have been translated to English and to some extent rewritten from readability, but the underlying meanings have not been changed.

4.1 Imperative Programming

Categories related to imperative programming were the most common after the analysis. A total number of 13 categories where identified. These were organized in 3 super-categories for easier overview in this paper: a new mindset, basics, and design (Figure 1).

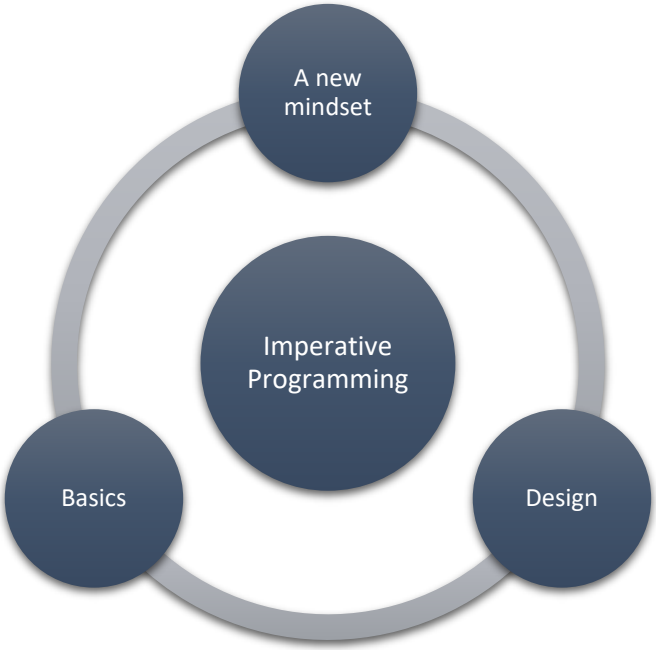

Figure 1: Super-categories organized around the central category 'Imperative Programming'

Study participants state that programming requires a new mindset that is often challenging for students. It requires, for example, a new way of thinking, understanding, abstracting, and looking at the whole. This new mindset is something that the game should address according to participants. Further, it is highlighted in the material that some students have difficulties to move from theoretical knowledge about programming to writing code that works. It is suggested that the game could address this, and other challenges that students face when learning programming, through debugging and problem-solving exercises.

In the collected material, participants highlight, for example, programming basics such as variables, selection, iterations, operators, lists, functions, and syntax. To some extent, it differs between the participants if they find some specific programming basics as challenging or easy for students in general. One participant state that “It’s relatively easy for many to understand how to create the fundamental building blocks of programming.”. While another participant state that “Many are in a hurry to advance and gets sloppy with the basics.”. However, most agree that programming basics should have a central role in the game.

Lastly, study participants gave several suggestions for game design elements and games that they liked. Among these, Codewars, Scratch and RPG-style games were mentioned as examples of what the participants liked. Besides these, participants highlighted that the game should have a point system, encourage play, be dynamic to the player’s skill level, and not be boring-looking. One participant state that “I think it’s important that the game show progression, that you can see how far you have come and how far you have left”. Participants also noted that the game should visualize programming for the students.

4.2 Object-Oriented Programming

Some of the categories identified through the analysis where more relevant in relation to object-oriented programming (OOP). These have been organized in the categories: classes and objects, OOP mindset, and methods (Figure 2).

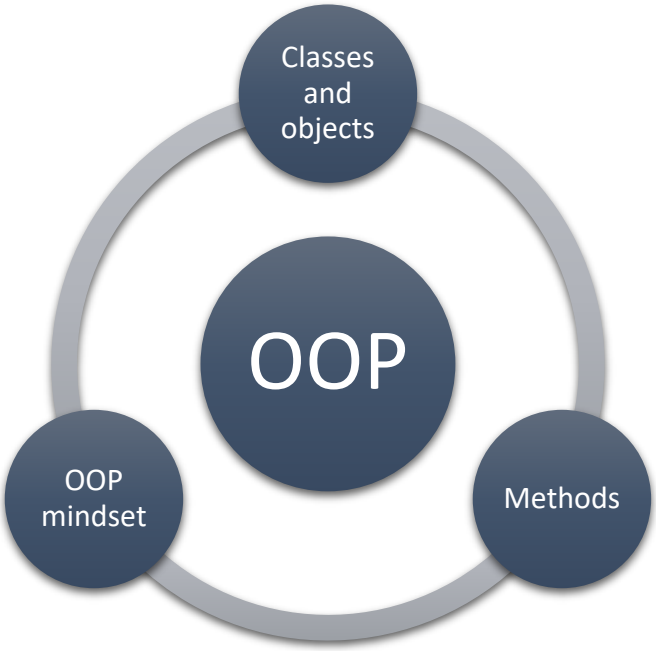

Figure 2: Categories organized around the central category 'Object-Oriented Programming'

Regarding classes and objects, study participants highlight different views if students find this challenging or easy. One participant state that simple classes and inheritance is often easy for students, while another participant state that "It's the same with classes, there it varies from not being able to write a simple class to being able to write a class and its content but not understanding how to use it".

In relation to classes and objects, study participants state that students have challenges with learning the concept of methods. This can be especially challenging if they just have grasped the concepts of variables, selection, and iterations. One study participant state the following about students' challenges with methods: "Regarding specific programming techniques, my perception is that many have problems with the transition to methods, classes and objects".

As in the previous section with programming as a new mindset, object-oriented programming is highlighted in the collected material as yet another level of difficulty. It is noted that object-oriented programming requires the students to look at data and logics as a whole, which can be challenging. One participant expresses the following about the challenges of learning object-oriented programming: "Even the simplest program requires more lines of code that you must learn by heart. Just like a musician needs to practice the difficult passages to get them in the muscle memory, a programmer needs to practice and memorize".

5. Discussion

In this section, the results from the study are discussed and compared to the theoretical background to identify important design concepts for the development of a need-based educational game on computational thinking (CT). However, the discussion is mainly focused on the results concerning imperative programming. The reason for this being that imperative programming was highlighted to a larger extent in the collected data and is more commonly associated with fundamental programming courses. This makes imperative programming a better alternative for design and development of a need-based educational game on computational thinking, compared to object-oriented programming. The notions brought forward for OOP in this paper could be further investigated in a future study and be part of a second game development project.

5.1 Actions

What the player can and cannot do in the game is of course a central aspect of game design and should be carefully considered in the development. Further, the player's interaction with the game can be related to the concepts of action possibilities (affordances) and constraints (Norman, 1999; Gibson, 2015; Bower & Sturman, 2015). Similar to Norman's (1999; 2008) statement of perceivable action possibilities as a crucial part of design, participants in the study highlight actions they consider important for an educational game on CT. Players should for example be able to practice the basics of programming, such as variables, selection, iteration, and syntax.

This was considered important by many of the participants in the study, although some experienced that students already find this easy, while other experienced that students could be sloppy with the basics. Players should also be able to perform actions in the game that support them in developing a new mindset, which participants in the study highlighted as necessary when learning programming.

5.2 Engaging

Participants in the study have highlighted that it is important that the game, for example, encourages play, is dynamic to the player's skill level, and is not boring-looking. In short, the game should be engaging. Emotional design could be a path for achieving engagement in game design, especially the three levels of visceral, behavioural, and reflective design (Norman, 2005). Participants' notion of that the game should not be boring-looking could be a way of stating that it should be attractive (visceral). That the game should support players in moving from theoretical knowledge to practice, writing code, is about the usability of the game and could be said to relate to the behavioural level of emotional design. The reflective level of emotional design can be difficult since it refers to the image of the user, and this can be different between different users. For example, participants stated that they liked Scratch, Codewars, RPG-style games and so forth. It is therefore important to consider how the visual design of a game affect users with different preferences.

5.3 Sustainable

Sustainability was not directly addressed by any of the participants in the study, but it is still an important concept for game design to consider, since development have impact on what has been labelled as environmental, social, and economic sustainability (Mota et al., 2015; Azapagic et al., 2016). Similar to Blevis (2007) recommendations for sustainable interaction design (SID), game design should incorporate sustainability in the values, methods, and reasoning for game development. For example, game design should be considerate of the direct and indirect impact on environmental, social, and economic sustainability. This could include what values the game promotes, how the game is to be maintained and updated after launch, what methods and techniques are used for development, and how resource intensive these are.

5.4 Limitations and Future Research

Data collection for this study consists of 15 structured e-mail interviews with higher education teachers and with that said, the study has limitations that should be addressed. Because of the relatively small sample size, findings from this study should not be understood as a generalisable understanding of higher education teachers' perceptions or preferences on the topic for the study. Authors suggest that future research should investigate design concepts for development of need-based educational games further, preferable by quantitative methods, to complement the results from this study. Focus for this paper has mainly been on investigating and discussing design concepts for educational games related to design theories. The analysis and discussion could have focused more on comparing the study's results to previous research and theories on game design. This should be addressed in future research. Lastly, according to Grounded theory the conducted phases of open and axial coding should be followed by confirmatory coding. Future re-analysis of the collected dataset should be revised and refined with descriptions of the relationships between sub- and super-categories.

6. Conclusion

This paper has investigated higher education programming teachers' perceptions about what students find easy and challenging when learning programming, in order to identify important design concepts for the development of a need-based educational game on computational thinking (CT). The paper has mainly focused on CT-concepts relating to the fundamentals of programming courses and the imperative programming paradigm. Through a discussion, where results from the study are compared to a theoretical background, the paper derives at three important design concepts for development of a need-based educational game: actions, engaging, and sustainable (Figure 3). The conclusion, and recommendations, of the paper is that a need-based educational game should consider what actions the player need to perform in order to learn, what design and visuals the player find engaging, and what impact the game has on environmental, social, and economic sustainability.

Figure 3: Conceptual design-model for a need-based game design

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PIXEL: Challenges of Designing a Professional Board Game for Astronomy Education

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Abstract: PIXEL - Picture (of) the Universe is a board game developed by INAF - Italian National Institute for Astrophysics in collaboration with GAME Science Research Center. The game simulates the astrophysics research environment, particularly emphasising the observation and study of cosmic bodies at different resolutions. Image resolution is a crucial element in astrophysics, but the intrinsic complexity and challenges of making high-resolution images of the distant Universe are not easily and generally perceivable. We envisioned PIXEL driven by this challenge. Games intended to engage students with science either concentrate on the contents to foster the learning process or focus on life skills solicited by scientific practices. Game mechanics are then either a leverage of scientific knowledge or a science-like behavioural model, depending on the expected outcome of the game-based learning process. In addition to that, game-based learning in STEM (Science, Technology, Engineering, Mathematics) generally is designed by science practitioners and science communication and education experts. The design process of PIXEL has been a novel joint effort between scientists, science communicators, professional game designers, and game-market and award advisors. We produced a game in which the mechanics are the core of scientific learning, implicitly telling about science while making the player experience it. The innovation of this process is to obtain a game that encountered positive feedback both from the community of game experts and the educational context. The final output is a professional board game suitable for STEM education that promotes scientific citizenship in the audience. In this work, we discuss the game design process and describe how we included our scientific educational messages of image resolution and research dynamics as processes within the game mechanics without making them explicit during the gameplay. We also present a preliminary engagement evaluation of PIXEL and its efficacy in delivering implicit scientific messages through its mechanics.

Keywords: Game design, Game-based learning, Astrophysics, High school education, Intersection of professionalisms

1. Introduction

Many pedagogical studies have pointed out the effectiveness of play as an educational tool (Setiawan & Phillipson 2019; Yunus & Zaibon 2021; Nurtanto et al. 2021; Zourmpakis et al. 2022). In particular, the game-based learning (GBL) methodology has proved to be highly successful when applied to STEM education, reporting increased learning outcomes and better attitudes toward science in groups of students involved in GBL (Li & Tsai 2013; Setiawan & Phillipson 2019; Papadakis et al. 2023).

In the framework of the so-called game-based science learning (GBSL), the involvement with disciplines can be achieved through games making the subject more enjoyable and fun also for younger target ages (Zourmpakis et al. 2023; Zourmpakis et al. 2022), fostering a more permanent and effective learning process (Beltozar-Clemente et al. 2022; Campos-Pajuelo et al. 2022; Papadakis et al. 2023). On the other hand, players can practise many transversal and generic soft and life skills, not necessarily specific to the disciplinary content, such as problem-solving, communication skills, and teamwork. (Kirriemuir & McFarlane 2004; Qian & Clark 2016; Nurtanto et al. 2021; Sin Yoon & Khambari 2021).

As such, scientific thinking is one of the most relevant competencies that GBSL try to solicit through games. Scientific thinking skills are not merely limited to the scientific research environment but belong to our daily lives. In this framework, Morris et al (2013) introduced the concept of scientific literacy as "the skills that are

required by citizens in a scientifically advanced democracy". Barab et al. (2007) state that it is up to science education to help students to develop skills necessary for dealing with 21st-century challenges. According to these definitions, scientific "literacy" has very little to do with knowledge intended as a set of notions, and it is more likely to be interpreted as the awareness of the processes and paths that lead to scientific knowledge, building upon critical thinking and the scientific method.

Applying these ideas to GBL, game mechanics either can be unrelated to the contents of the expected learning process, only being the means of the gamification of sciences, or they can represent themselves as the learning object and an explicit reference to the discipline can help to put the process into context (Sin Yoon & Khambari 2021).

In this study, we argue that a game design focused on mechanics can be a powerful way to use games to empower learning and awareness of sciences. In particular, when they never use disciplinary prerequisites to proceed and succeed in the gameplay nor ever introduce the verification of the disciplinary learning outcomes.

For this aim, game mechanics must mimic specific topics to be effectively experienced and not confusing. A multidisciplinary approach is needed, involving different research professionals to best focus on the contents (Yunus & Zaibon 2021, Sin Yoon & Khambari 2021).

Most importantly, game mechanics must keep the game faithful to its nature, of a playful environment not aimed at learning, but in which learning happens, almost by chance, wanted but undeclared (Toniolo et al. 2023). For this aim, a professional game designer, not only an expert in educational gamification, should be a crucial character in game design.

With this in mind, we designed PIXEL-Picture (of) the Universe, an astronomical-themed board game with the aim not to teach astronomical content but to improve the development of scientific thinking skills in players and also to engage the general public with the world of scientific research and Astrophysics. To reach this goal, the design of PIXEL was a multidisciplinary collaboration between astronomers of INAF - the Italian Institute for Astrophysics and professional game designers of the GAME Science Research Center. The final product is a board game in which we tailor the mechanics to reproduce astronomical observations at incremental resolutions and realistic research processes of an observatory, such as technological development, multidisciplinary research team, and publications. In this way, we let players have first-hand experiences of such scientific concepts and processes by playing with them and using them as a central part of their strategy to win the game.

This paper is structured as follows: in Sec. 2, we show PIXEL in detail and introduce how to play the game. Section 3 exploits the multidisciplinary design process, stressing how we balanced scientific content and the fun of the game. We achieved this result by implementing specific game mechanics that mimic astronomic scientific concepts and processes, as described in Se. 4. In Sec. 5, we present the feedback we collected to test PIXEL entertainment and scientific engagement, and we summarise our conclusions and introduce future developments for this project in Sec. 6.

2. PIXEL: Description of the Game

PIXEL-Picture (of) the Universe is a board game developed by astrophysicists of the Italian National Institute for Astrophysics (INAF) in collaboration with Andrea Ligabue, a professional game designer, game-market and award advisor of the Game Science Research Center.

PIXEL is a competitive game of 60-90 minutes for 3 to 5 players designed to simulate the astrophysics research environment, with particular emphasis on the observation and study of cosmic bodies at different resolutions.

We envisioned PIXEL for GBL activities in secondary schools for students 14-16 years old, but the final target of PIXEL also includes board gamers and board game lovers beyond the educational scope of the game, lowering the minimum target age besides the GBL activity to 12-13 years old.
In PIXEL, each player has to manage an observation research centre to observe three celestial objects, such as galaxies, nebulae, and objects of the Solar System.

As the game proceeds, each player shall manage Resources and the Research Centre to lead the researchers' team, specialise them, improve the laboratory, publish, and observe more and more portions of the Universe using their Ground and a shared Space Telescope, gaining the points that will determine the winner at the end of the game.

Figure 1: PIXEL played at PLAY game festival 2023

To observe the celestial bodies, the players place and flip tiles corresponding to different portions of the celestial bodies in the game at incremental resolutions. We have four different resolution levels of the Celestial Objects and, as the resolution goes higher, the players will discover more and more details of these Objects and solve their goals and projects, as shown in Fig. 2. To observe at higher resolution, the player shall improve the resolution power of both the Ground and Space Telescopes they have available for their observations.

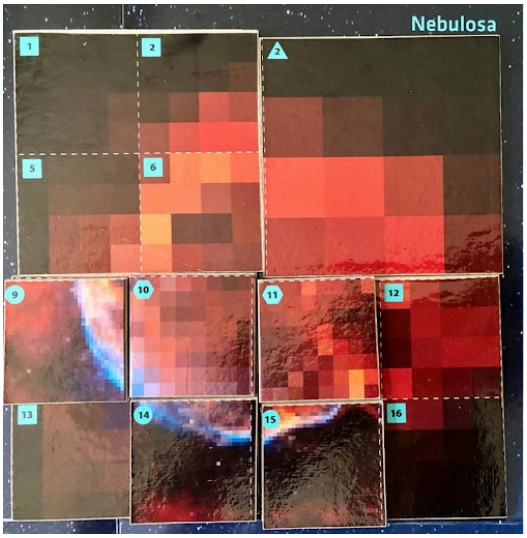

Figure 2: How an image of the Medulla nebula is reconstructed during the game. The symbol in each tile identifies the resolution. From the lower to the higher: triangle, square, hexagon, circle

2.1 How to Play

In this section, we introduce how to play PIXEL. A complete description of the game's rules can is available at the following link: https://youtu.be/yYwoGZCmkkU

During the setup of the game, each player obtains a Research Centre to manage, starting from Level 1, with 5 Resources, a Ground Telescope at Level 1, an Objective card corresponding to one of the Celestial Objects used for the game, 2 Project cards, and 3 Researchers.

The Objective cards represent the main individual observation goal of the game; on each Objective card is indicated a specific resolution tile of a Celestial Object. At the end of the game, if that tile is revealed, the player with the Objective card scores points according to how much they observed the Object during the game. The Project card instead gives points during the gameplay when players accomplish specific observations or

technological development of their Research Centre. Finally, the Researchers allow players to make actions in the Action phase of each turn.

Every PIXEL game goes on for four turns. Each turn is divided into four different phases: the Preparation phase, the Action phase, the Observation phase and the Publication phase. At the end of the four turns or when someone reaches the common goal, the game ends, and players calculate the Scientific Prestige (SP) points. Who scores the most SP points wins the game.

In the Preparation phase, players collect Resources to invest in their actions, obtain new Project cards, and the turn order changes in inverse order of SP points. Then, an Event card is revealed and immediately applied for the current turn.

In the Action phase, players use their Researchers to carry out one action at a time while spending the relative Resources. There are several actions available: for example, improving the Space and Ground Telescopes, booking the use of the Space Telescope for this turn, specialising or hiring a Researcher, buying new technologies, and publishing.

In the Observation phase, players use their Ground or Space Telescopes to observe one or more portions of the Celestial Objects. An observation consists in placing or flipping a tile of the specific Object according to the resolution allowed by the level of the Telescope in use. As players observe a specific Object, they advance in the Observation Grid of that Object, at some points gaining SP points and Publication cards of that category.

Focusing the observation on a specific object is also crucial in the final Publication phase of each turn, in which players obtain one extra Publication card connected with the Object category in which they lead observation, such as Galaxies, Nebulae, and Planets. At the end of the game, Publications will give SP points according to how much players focus on the same category or collect cards of different categories.

3. The Design Process

PIXEL is a multidisciplinary collaboration between INAF astronomers, who want to disseminate astronomical and scientific knowledge, and GSRC game designers, who want to create an engaging and feasible board game. For this reason, the co-design process sometimes compromises different choices and premises but enriches each other's views and ideas. Each implementation was discussed, balanced and playtested.

The basic idea of PIXEL arose from the playful hands-on activity for 9 to 10 years old children named ‘‘Talking about Resolution” (Varano & Ricciardi 2018; Ricciardi et al 2019) developed by INAF researchers. During this activity, participants have to recreate a recognisable image for their mates in the less time possible. To do so, they have to choose and insert pegs of different colours and sizes in the holes of a board (Fig. 3). The pegs are intended to represent the pixels of a digital image.

The main goals of this activity are:

- to introduce core concepts of astrophysical imaging (such as spatial and chromatic resolution and sampling); without explicitly introducing them, leaving much space for personal intuition and autonomous discovery;
- to encourage all children's commitment through playing thanks to familiar toys.

The activity was tested in several contexts between 2018 and 2019, such as schools, interactive science exhibitions, and events dedicated to science outreach. "Talking about Resolution" received positive feedback, and facilitators noticed a deep engagement of children with the processes and challenges of image representation through image units. As a follow-up to this activity, a master thesis analysed the activity within the framework of the game-based learning methodology, intending to identify its strong points and include them in the design of a board game (Varano & Toniolo 2021).

As a result of this work, we decided to design a board game around mechanics that lead to the construction of an image at different resolutions.

The game was meant to be engaging and entertaining, before (or better without) being educational.

In addition to that, as in "Talking about resolution", the main goal of the design remained to keep clean of foreword astronomical concepts to succeed in the gameplay and leave them to be autonomously (and possibly unconsciously) extrapolated by the game experience. That’s why we asked for the collaboration of a professional game designer, alien to the astronomical research field.

Figure 3: In the activity "Talking about Resolution" children use pegs of different sizes and colours to represent the image located under the board.

The first issue we faced in the game design process was the idea, suggested by the game designer, to reinsert an astronomical setting to take advantage of the fascination this branch of knowledge benefits in the public imagination and also to better stick to our public image, being this the "brand" expected for an activity proposed by an Institute of Research in Astrophysics.

With this choice, we abandoned the idea of using familiar images and presenting the concept of image resolution as general and transversal to all disciplines, linking specifically the process to astronomy. In this way, we lost the materiality of using pegs as pixels because of the impossibility of recreating recognizable astronomical images with sufficient resolution using pegs or other material units for each pixel. To preserve some materiality in the game mechanics and simultaneously reach a higher resolution for astronomical images, we introduced the innovative tiles mechanisms we described in the Observation phase of the game (see Sec. 2.1). In this way, we reproduce 4 different images of the same objects at incremental resolutions, from 8x8 pixels divided into 4 tiles, up to 128x128 pixels divided into 16 tiles. This choice brings benefits in terms of appearance, replicability and spread of the resolution mechanics in the game.

The choice of using astronomical images pushed us to design the board game to target higher ages concerning the activity "Talking about Resolution", from 12-13 years old to adults.

We analysed several board games already available in the market (Inchingolo et al 2023; Cardinot & Fairfield 2022; Engelstein & Shalev 2019) and started implementing more suitable mechanics that would lead to building images at higher and higher resolution. One of the most inspiring games we considered was "Genotype: A Mendelian Genetics Game" [Genius Games], which allows players to simulate research in Genetics, combining worker placement and resource management mechanics to carry on their research using specialising cards to draft players' facilities. We noticed that worker placement and resource management mechanics can be generalised to simulate any scientific research process. Using these mechanics, we tailored game actions to represent astronomy research processes like technology development, hiring new researchers, and more.

The role of professional game designers in this phase was crucial to transpose in efficient game mechanics the information provided by the astronomers about how astronomy research works. We jointly and accurately studied the correspondence of each character and action with the actual astrophysical research, ending with introducing in the game people and processes and their specific roles in obtaining the scientific results. In Sec. 4 we detail the correlation between the game mechanics and the related astrophysical concepts.

These concepts are implicit in the game, sticking to the initial idea of a game fostering autonomous learning instead of promoting it. For this reason, we design the mechanics to require no former knowledge to proceed in the game.

We introduced in PIXEL also explicit disciplinary aspects, by using descriptions and images of actual astronomical objects in Publication cards and the cards presenting the celestial objects available for the game. These elements are optional and not connected to the game mechanics.

A crucial part of the design process was the extensive time we spent in playtesting these mechanics, balancing the resource cost for each action and their effects, improving the scoring system and minimising micro-management, which otherwise would have distracted too much from the scientific process and the core goal of observing the objects in play at higher and higher resolution. In particular, we want to underline the importance of testing the game with targets of different game experiences and scientific backgrounds or interests. In this way, we collected feedback about not only the learning PIXEL fosters but also (and perhaps mainly) about the engagement and entertainment experience while playing.

While going through the design process, we decided to use the most gender-neutral language possible to show that science can overcome gender barriers. Being Italian the design language, this was not an easy operation since most of the words have only male and female versions, and the tendency is to use the male version for collective and generic reference to characters. For example, the translation of ‘‘researcher” is ‘‘ricercatore” (male) and ‘‘ricercatrice” (female), while ‘‘researchers” is usually translated as ‘‘ricercatori” (male plural). To help us with this matter, we collaborate with Vera Gheno, an Italian socio-linguist expert on inclusive language. As a result, we reduced the use of gendered sentences, preferring alternative but still natural-sounding paraphrases. When this was not possible, as for the example above, we introduced in our game the symbol “ə” (shwa), which is one of the suggestions to make words gender-neutral and overcome gender-binary references: in our example, the translation of both ‘‘researcher” and ‘‘researchers” will be ‘‘ricercatorə”.

4. Correlation With Astrophysics

The novelty of the PIXEL design process is how we design game mechanics to stimulate scientific pondering during the gameplay instead of delivering scientific knowledge using the game theme and contents. In this section, we detail the correlation between PIXEL mechanics and their relevance to astrophysics research and processes.

We drafted the mechanics to communicate and explain how astrophysical image resolution and scientific research environments work.

PIXEL theme and mechanics recreate the environment of astrophysics research and relations: players make decisions autonomously and collaborate with others, as in actual research. They have to combine different professionals to improve the level of the instruments of the research centre. They have to manage the observation time and resolution to choose whether to study small details at high resolution or the entire body at low resolution. As in actual research, results are shared with the community (in this case, the other players), and publications help obtain more winning points.

We kept the mechanics as relevant as possible to the reality of the research environment, without the presumption of being a realistic simulation, still offering players as many possible cues for thought. For example, in PIXEL each player has a specific observative goal to reach (the Objective card) connected with a particular portion of the Celestial Objects in the game. In actual Astrophysics research, we do not often know a priori where to observe specifically to obtain our scientific results, but this mechanic simulates high-resolution observations resting on the results of previous low-res general surveys.

Table 1 collects all the mechanics we designed to simulate how observation works in astrophysics, with particular emphasis on image resolution and technology development necessary for the observations. For all these mechanics, we explain the connection with Astrophysics research.

Table 1: Analogies between game mechanics (left) and astrophysics research (right)

Game Mechanics	Correlation with the Astrophysics Research
Highest-resolution tiles are smaller than the lowest-resolution ones.	Obtaining an image of high resolution requires more observation time, which corresponds to placing a tile in the game.

Game Mechanics	Correlation with the Astrophysics Research
Observations can be obtained both with a private telescope (ground) and with a public one (space).	Astrophysical research can be both competitive (for example when trying to be the first to observe a phenomenon) and collaborative.
Doing an observation gives an advantage to the player who made it, but the tile revealed on the board is available to all players.	Being the first to study a specific object gives an advantage to the researchers and their research centre, but data and the results obtained by the observation are shared with the scientific community.
Improving the public telescope needs fewer Resources than improving the private ones.	Public telescopes are the results of international or global collaborations.
Ground observation can be affected randomly during the game by good or bad observational conditions, while the Space telescope is immune to this effect.	Atmosphere conditions affect ground observation, while observations made with space telescopes are immune to these effects since they orbit above Earth's atmosphere.
Investing in the technological development of telescopes and their research centre allows for observing higher-resolution images.	In Astrophysics research, we constantly invest in technology development to improve the study of the Universe with more-detailed observations.
To place a higher-resolution tile, the corresponding lower-resolution one needs to be already observed on the board.	We reproduce the idea of astrophysics research that requires often a low-resolution study of a portion of the Universe (called "survey") to locate the interesting spots where to focus for a more detailed study with higher resolution observations.

In Table 2, instead, we collect all the mechanics we introduced to correlate with how astrophysics and the scientific research processes work, like the management of the research centre, research activities, and publications.

Table 2: Analogies between game mechanics (left) and research process (right)

Game Mechanics	Correlation with research dynamics
Every player has several researchers available to do his/her actions.	Scientific investigation is a collaborative and team effort of researchers, not a stand-alone activity.
The researchers can be specialized in different professionality, like theoretical, numerical and observation experts, project managers, engineers, and communication experts.	The management of a research centre requires a team not only of researchers but of many professionals that help with fundraising, communicating with the public, and implementing new technologies to progress in the research.
The number of Publication cards gives SP points at the end of the game.	Publications are a way to communicate each own investigation within the community and increase the scientific prestige of the centre.
Lead the observation in a specific object lets players gain Publication cards connected with the category of the observed object.	Focusing the research on a specific topic and category will improve your chance to publish on that topic and gain Scientific Prestige.
Resources are not a way to directly collect SP points.	A capable research centre is not one with more resources but with higher scientific prestige.

Game Mechanics	Correlation with research dynamics
Events at the beginning of the turn can affect players' strategy during the game.	Not always scientific research can be done as planned, but often researchers need to adapt their studies to external events.

5. Engagement and Scientific Stimulation Efficiency Evaluation

We designed PIXEL aiming for a professional and engaging board game in which astronomical contents can emerge through game mechanics during the gameplay. We test this purpose with a questionnaire after a single gameplay in different public events, like the 2021 and 2022 PLAY Game Festival in Modena, the 2021 and 2022 Lucca Comics and Games, and the 2022 and 2023 Science Festival in Rome. The scope of this questionnaire was not to test PIXEL's efficiency as an educational tool. Instead, we want to verify PIXEL enjoyment and appeal for teenagers and young adults (16-25 years old) with experience in board games. Simultaneously, we want to investigate how players may perceive the scientific contents we embedded in the mechanics.

To evaluate the engagement, we asked more than 200 people to assign a score on a Likert scale from 1 to 7 to several attributes about Pixel, both positive and negative responses. We evaluate the following PIXEL characteristics: funny, not attracting, absorbing, pleasant, boring, interesting, and entertaining.

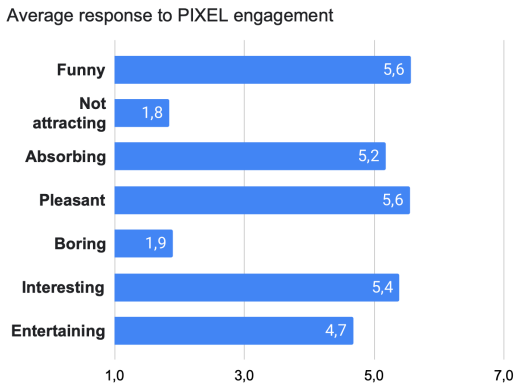

Figure 4: Likert scale for average response to PIXEL engagement.

Figure 4 shows the average engagement response. For our sample, the game is overall funny (5.6), pleasant (5.6) and interesting (5.4).

We put the “inverted” values of the responses to the three negative attributes to average them with the Likert value of positive attributes. For example, for the “boring” characteristic, we used the value 7-1.8=5.2 to average it with the other positive characteristics. In this way, we obtained positive feedback about the engagement and entertainment of PIXEL, with an average of all the attributes of 5.2/7.

We also asked the same 200 people for their feedback on our design aim to stimulate scientific topics within game mechanics. To do so, we created a list of 10 different scientific statements, 7 of them relevant to the science implemented in the game’s mechanics (as discussed in Sec. 4 and listed in Fig. 6). We request our sample to indicate the three sentences that are better referred to the game.

The probability of randomly answering our survey with at least one relevant sentence is 7/3, giving a random ratio of relevant/not relevant sentences to 2.3. From the collected answers, this ratio increased significantly to 13.6.

Figure 5 shows the normalised occurrence frequency over the 600 answers collected (3 for each of the 200 people) for each of the 10 statements. We observe that the most frequent answers are “Improvement of technologies brings to an improvement of observation resolution” (19,8%), “scientific research is a collaboration of different professionality” (16,3%), and “high-resolution images require more observation time” (14,9%).

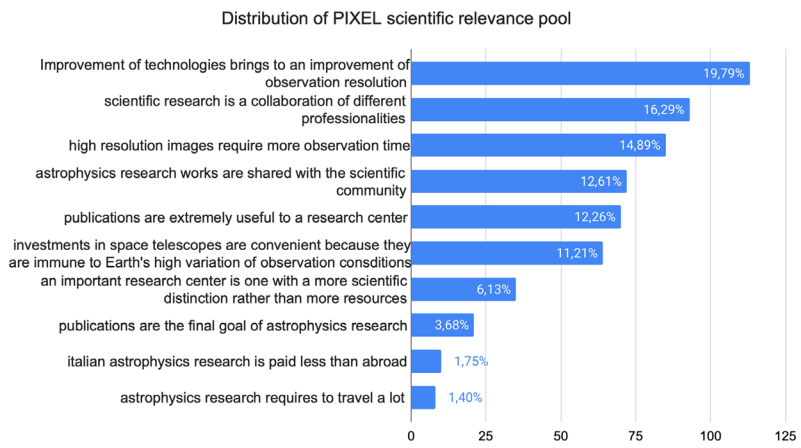

Figure 5: Normalised distribution of answers to PIXEL scientific evidence survey.

We conclude that PIXEL can stimulate scientific content in astronomy through its game mechanics after a single gameplay. In particular, people noticed the correlation between image resolution, and the required observation time and technological development necessary to get that resolution. Players also perceived the collaboration of different professionals as crucial to run an observation centre.

6. Discussion and Future Work

PIXEL - Picture (of) the Universe is an innovative astronomy board game we designed to be engaging and entertaining for a target of 16-25 years old without previous knowledge of Astronomy. We envisioned PIXEL as an educational tool for GBL activities in high schools. Contrary to most available educational games, in which the educational topic is explicit, in PIXEL, the mechanics are the core of scientific learning, implicitly telling about science while making the player experience it.

PIXEL was a co-design result between INAF astronomers and game designers of the GAME Science Research Center. In this work, we described the design process, emphasising how we balanced the engagement and entertainment of the gamer and the necessity to include actual scientific concepts and research processes. As a result, we embedded in PIXEL game mechanics the astronomical concepts of image resolution and how an astronomical observation centre works.

We shared the PIXEL design process since collaborating with game designers is not a diffuse opportunity in educational environments. In particular, it is possible to generalise some of the conclusions of this design process to other STEM disciplines helping other GBL practitioners in designing their games. For example, the game mechanics of worker placement and resource management are perfect for simulating any scientific research process, not only the astronomy one.

Another practice we learned from the design process was the necessity of testing the game with our teenager and young adult targets until we converged on a game suitable for our educational and engaging porpoises. For this reason, we collected feedback on these porpoises with a questionnaire after a single PIXEL gameplay in different public events, obtaining from more than 200 people a positive score of 5.2/7 on average. Same people confirmed our design idea of stimulating scientific thought with PIXEL, answering that in the gameplay, they noticed the correlation between image resolution and the required observation time and technological development necessary to get that resolution. Players also perceived the collaboration of different professionals as crucial to run an observation centre.

The positive feedback indicated that PIXEL is a professional board game that promotes scientific citizenship in the audience.

To test the efficiency of PIXEL as an education tool for GBL activities, we developed a long-term education project in 5 different high schools in Italy. We are currently working on data analysis and we will present the results in future works.

We understand some of the limitations connected with this co-design process. First of all, the time and economic investment in PIXEL production may limit the accessibility and distribution of the game, especially considering

the diffusion of digital and video games in society and education. Without sacrificing the materiality of the board game, we are currently working on a print&play version of PIXEL that will ease its usage in educational environments.

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Enhancing Mathematical Reasoning in Primary School With the Strategic Board Game Othello

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Abstract: This study explores how the board game Othello can enhance primary school students' mathematical reasoning. Mathematical reasoning is increasingly emphasized in international mathematics curricula, yet both teachers and students face challenges in teaching and learning this important skill. Research shows that strategic games, like Othello, can develop thinking abilities related to mathematical reasoning by providing a context for students to engage in reflective thinking, anticipate future moves, and develop reasoning strategies. However, there is a need to understand how teachers can effectively utilize these games in the classroom to foster mathematical reasoning. We address this, through a design-based research approach consisting of a hermeneutic literature study and the development of design principles for a teaching intervention in a fifth-grade classroom. Data from the intervention is collected through participant observations and group interviews. The findings suggest that Othello can serve as a context for students to engage in mathematical reasoning by making and justifying claims and presenting logical arguments. The study proposes three design principles to scaffold mathematical reasoning during Othello gameplay. These principles focus on introducing and reinforcing the use of the "if...then" formulation, promoting exploratory talk, encouraging reflection on strategies, and fostering collaborative reasoning. The results indicate that the design principles positively impacted students' ability to reason mathematically. This paper contributes to the field of mathematics education and game-based learning by providing a practice-oriented perspective on designing mathematical instruction for reasoning using a specific board game in a primary school setting. The findings offer insights into the potential of strategic board games like Othello to enhance students' mathematical reasoning skills. The design principles proposed in this study can guide teachers in developing effective instructional approaches to support students' mathematical reasoning development.

Keywords: Mathematics education, Mathematical reasoning, Exploratory talk, Game-based learning, Strategic board games, Primary school students

1. Introduction

The study aims to understand how the board game Othello can be used to design teaching interventions developing primary school students' mathematical reasoning. We define mathematical reasoning as being able to make a claim of a mathematical nature and to argue why this claim is true by explaining and justifying one's ideas. This definition is inspired by McFeetors and Palfy (2018) and Niss and Jensen (2002) and will be elaborated in section 3.1. Mathematical reasoning is considered a central part of doing mathematics and has recently gained a prominent role in international mathematics curricula and mathematics education research (Jensen & Skott, 2022). However, mathematics teachers find it challenging to teach mathematical reasoning and students find it difficult to learn (G. J. Stylianides et al, 2017). Strategic and logic games have been shown to develop aspects of thinking related to mathematical reasoning (McFeetors & Palfy, 2018) like generalizing and reasoning for a winning strategy (Day 2014). Strategic board games can potentially contribute to the development of students' mathematical reasoning by providing a context for reasoning in the development and testing of hypotheses as they encourage students to anticipate future moves and reflect on game situations (Olson, 2007). But there is still few intervention studies aiming to support teachers in designing learning experiences with mathematical reasoning in primary school (G. J. Stylianides et al, 2017). Through a design experiment (Cobb et al, 2003) with the board game Othello and a practice-oriented perspective on how primary school teachers can design mathematical instruction for reasoning, this study addresses this research gap. We do this by posing the research question: What design principles are relevant for planning lessons promoting students' mathematical reasoning with Othello?

2. Research Design

Our methodological research approach is Design-Based research (DBR) (Barab & Squire, 2004) which is well suited for developing new forms of instruction, enabling researchers to iteratively design, refine, and test interventions in real-world settings (Cobb et al, 2003). This approach considers the complex interactions

between learners, the instructional environment, and the content being learned. The iterative process allows researchers to refine their understanding of student learning and identify design principles that inform the development of new instructional approaches (Cobb et al, 2003).

This study is the first iteration with the aim to create sound design principles for further testing and so the validity of the principles is open to critique based on the lack of iterations. Our research design consists of three parts. First, a hermeneutic literature study (Boell & Cecez-Kecmanovic, 2014) of mathematical reasoning and games, supplemented by identifying Othello's potential for reasoning which provides the theoretical frames for the study. Secondly, a design of a teaching intervention generating guiding design principles (Hanghøj et al. 2022). Thirdly, an intervention in a fifth-grade math class (approx. 12-year-olds) to investigate and refine the design principles. The intervention spanned three 120-minute lessons. The class was recruited by our collaborator who is the chairman of the Danish Othello Association. The intervention teacher responsible for conducting the lessons, was Anna Louise Eriksen, co-author of this paper.

2.1 Design Principles

As proposed by Hanghøj et al. (2022) we created design principles to articulate our theoretical assumptions into specific guidelines for scaffolding mathematical reasoning in the intervention. This was guided by results from the hermeneutic literature study and the analysis of Othello (see section 3). The design principles are intended to be used when designing mathematics lessons aimed at using Othello to develop primary school students' mathematical reasoning. They are aimed at engaging students in 'exploratory talk' (Mercer et al, 1999) as a means of expressing mathematical reasoning. To benefit the most from the design principles the lessons should be structured as the three-phased model for inquiry-based mathematics teaching (Blomhøj et al, 2022): 1) Setting the scene for the students' activities. In the intervention the primary component in this phase, is an initial didactic section where the teacher establishes the context for the following adidactic part (Brousseau, 1997). 2) Allow for sufficient time and freedom for students' independent inquiry-oriented activities. Here the students engage in the Othello activity. 3) Share reflections, experiences, and learning. In this phase the teacher refines and reinforces the understanding of the mathematical reasoning that emerged during the Othello activity by promoting a reasoning-focused classroom environment and encouraging students to share their strategies and thinking through inquiries about their thought processes (Whitenacke & Yackel, 2002).

To gather data, two of the authors performed participant observations (Creswell, 2014) during all three lessons, documenting observations in a detailed logbook and collected the materials produced by students. The observations were directed towards two pairs of students in the class and the teacher. Following the intervention, we conducted two semi-structured group interviews (Brinkmann & Kvale, 2015) with the two pairs of students. We recorded and transcribed the students' group work, the discussions in the classroom initiated by the teacher and the interviews. The collected data (logbooks, transcriptions, interviews, and student-produced materials) was examined in relation to the design principles and findings from the literature study by asking the following questions: Which aspects of mathematical reasoning were promoted in the intervention? How did the design principles support this and what were the challenges? With these questions, we aimed at understanding the three design principles potential for engaging students in exploratory talk when using Othello in a mathematics teaching practice.

3. Theoretical Frame

The theoretical frame for our investigation and understand mathematical reasoning in analog games was developed through a hermeneutic literature study (Boell & Cecez-Kecmanovic, 2014). This was done through a cyclical and iterative approach consisting of searching for literature, sorting, selecting, acquiring, reading, identifying, refining, searching, ect. In this process parts of the literature are continuously understood and related to the overall understanding of the phenomenon (Boell & Cecez-Kecmanovic, 2014). Our intention was to get a deep and broad understanding by continuously and consistently interpreting the literature in relation to other relevant literature. We used two overarching searches, one trying to understand mathematics reasoning in general and one related to analogue games. The searchers were a combination of searching for keywords in the Aarhus University search engine combined with citation searching (Boell & Cecez-Kecmanovic, 2014), in the curriculum for the master's in mathematics education in Denmark and articles found in a prior search for a review of digital games and mathematical reasoning (Jensen & Skott, 2022). See Eriksen and Nehammer (2022) for further details. The following two sections presents our results from the review that also act as our theoretical frame for understanding mathematical reasoning in analogue games.

3.1 Mathematical Reasoning

The literature study of mathematical reasoning found that different definitions of reasoning emphasize either structural or processual aspects (Jeannotte & Kieran, 2017). Structural aspects understood as; ‘A good' or 'a logically valid argument' (Lindhart et al, 2010), 'a chain of both formal and informal arguments' (Niss & Jensen, 2002) 'a reasoning that involves patterns' (delMas, 2004). The processual aspect, highlight that mathematical reasoning involves communication with oneself or with others in either writing or speech and is understood as; Definitions that emphasize processual structure include descriptions such as 'to justify', 'to modify', and 'to evaluate' (McFeetors & Palfy, 2018; Whitenacke & Yackel, 2002). Further we found arguments that that reasoning for arguments should be understood relative to the age and mathematical ability of the students (Lindhart et al, 2010). In agreement with the literature study, we define mathematical reasoning as being able to make a claim of mathematical nature and to argue why this claim is true by explaining and justifying one's ideas. This includes following others' arguments and being willing to reformulate one's own arguments if they turn out to be untrue because of another argument presented (McFeetors & Palfy, 2018; Niss & Jensen, 2002). To design for mathematical reasoning in class we aim to facilitate ‘exploratory talk’ (Mercer et al, 1999), a form of communication similar to our definition of mathematical reasoning, as it is characterized by students explaining and justifying their reasoning in a joint discussion, listening to each other, and positively accepting challenges from both the teacher and other students.

3.2 Development of Mathematical Reasoning in Othello

Othello is a competitive two-player board game played on an 8x8 board with identical game pieces with one white and one black side. Players compete to have most pieces of their color, either black or white facing up at the end of the game. Players take turns placing one piece on the board and flipping over any of the opponent's pieces that are sandwiched between her own pieces. There are no chance factors in the game and all information is available to both players making it a combinatorial strategy game (Fraenkel, 2002) a category of games that have potentials in developing students' mathematical reasoning (Day, 2014; Houssart & Sams, 2008). Specifically, Othello offers an opportunity for players to gain experience and recognize patterns in the game by understanding the relationship between the two variables, black and white. By combining our definition of mathematical reasoning with the understanding of Othello as a combinatorial strategy game we argue that the game can be used as a context for students to devise and present mathematical reasoning in the form of 'a good argument,' 'a logically valid argument,' or 'a chain of informal arguments' for a claim of mathematical nature (which relate to the structural aspects) and, by 'explaining' and 'justifying' their ideas (which relate to the processual aspects). In our intervention design we assume that there will be a progress towards refining claims through arguments. To assess this, we created a table that indicates progress in student reasoning and an envisioned example with Othello (see Figure 1). It is partly based on the taxonomy presented by Díez-Palomar & Olivé (2015) and draws a parallel between ‘exploratory talk’ and 'Interaction Type 3: Dialogic Interaction', that is characterized by students engaging in the interaction and establishing dialogues based on validity claims expressed in the dialogue.

Interaction type	Claim characteristics	Reasoning	Envisioned example
1: Exchange of information.	Claims without arguing by explaining and justifying.	No reasoning.	'It is disadvantageous to start.'
2: Non-dialogic.	Invalid arguments based on everyday experiences to explain and justify a claim.	Everyday reasoning.	'I win at Othello because I often play board games.'
	Invalid arguments based on an asymmetric power position to explain and justify a claim.	Reasoning based on an asymmetric power position.	'If I place my color in the corners of the game board, I will win because my teacher said so.'
3: Dialogic interaction.	Correct and meaningful arguments for a claim by explaining and justifying.	Correct and meaningful reasoning.	A good or logically valid argument: 'If I place my piece in this square, I can flip three pieces because I am trapping my opponent's pieces horizontally.'

Interaction type	Claim characteristics	Reasoning	Envisioned example
			A chain of informal arguments 'If I place pieces in the corner, my opponent cannot flip them, and then I have the opportunity to flip my opponent's pieces both diagonally and along the edges'

Figure 1: The Interaction types and associated types of mathematical reasoning, or lack thereof, that we expected students to be able to express in a game situation

4. Results

To improve clarity for the reader, this section is structured so that each design principle is presented first through our a priori intention for the principle and secondly through the analysis of the empirical investigation.

4.1 Principle one: Introduce and continually Repeat the 'if...then' Formulation

Intention: By presenting the 'if…then' formulation in the introduction and continually repeating this in the interaction with the students, the teacher can explicitly encourage 'exploratory talk'. The formulation can be used to express different degrees of reasoning in student dialogue ranging from mathematical reasoning to 'good' or 'logically valid argument' or a 'chain of informal arguments' for a claim by 'explaining' and 'justifying' their ideas (Mason, 2002). This can in different ways express that students are on the way to develop an advantageous strategy (Houssart & Sams, 2008).

Analysis: In the intervention, the teacher was explicit about the 'if...then' formulation in all introductory presentations for the double lessons. In the first lesson, this occurred after the students engaged in one-on-one play to internalize the rules, which is crucial if the game's potential for developing students' mathematical reasoning abilities is to be realized (McFeetors & Palfy, 2018). In the first two lessons of the intervention, several students expressed themselves in a way that was consistent with the following statement:

> *Student: 'If we place a piece there, then we can flip these three.'*

Here using the 'if...then' formulation, the students were able to explain and justify a claim with a simple but logically valid argument that considered the premises constituted by the rules of the Othello game. The simple arguments based on validity claims, which the students presented using the 'if...then' formulation, indicate an early use of 'Interaction Type 3' (Díez-Palomar & Olivé, 2015). In the second round of play, groups took longer than the first as: 'Several students take time to consider where to place their pieces while also using 'if...then' more in their conversation with their partner.' (logbook). Especially in the second and third double lesson, we find examples of students attempting to formulate a more long-term strategy by using the 'if...then' formulation as a basis for predicting up to three consecutive moves, which could be considered a progression in their reasoning. At this stage in the process, students were able to formulate chains of informal reasoning as opposed to the beginning of the intervention where they mainly presented simple but logically valid arguments. The following statement is an example of mathematical reasoning consisting of 'a chain of informal arguments' for a claim about the consequences of the game pair's choice of moves for the game's development and the opponents' opportunities:

> *Student: '...if we had placed it there, then our white piece would have disappeared. Then you the opponent) could have taken our white piece, and we couldn't have placed it there.'*

The active use of the 'if...then' formulations in the Othello activities indicate that 'design principle one' had a positive effect on developing students' mathematical reasoning through Othello. When the student pairs internally discuss their future moves during the Othello activity and using the 'if…then' formulations we saw several instances of 'exploratory talk' and what we will call a rich environment for developing mathematical reasoning. Further the use of the 'if…then' formulations were used to express increasingly advanced forms of reasoning through the intervention.

4.2 Principle Two: Allow one Pair to Compete Against Another Pair

Intention: Like most other classic and abstract board games, Othello is played in a one-on-one setup which actively discourages players from communicating about the moves they choose during the game. McFeetors and Palfy (2018) find that students have better opportunities to reason when they have both allies and opponents, and that students are more likely to both express and refine reasoning when they must justify a

move to a teammate. Therefore, to promote 'exploratory talk,' we organize the students in groups of four, with one pair playing against another pair.

Analysis: We observed in the first double lesson that students were more likely to produce reasoning when playing one pair against another pair, rather than when playing one student against another student and that the students produced more correct and meaningful reasoning as the intervention progressed. An example of this was when a student in the first round playing one-on-one made a claim without explaining or justifying why the claim was true:

Student: 'It will ruin everything for you if I place it here,'

In the second round, the same student made a claim where she now provided reasoning and explained why the claim was true:

Student: 'So I think we should block here because... if we put it there, then we turn here, but then they also have the opportunity to put theirs there, and then they also have all those.'

We understand this as a form of explorative talk as the students here exchange an argument and explain and justify their reasoning while also listening to each other. During the intervention the students became more inclined to listen to and evaluate each other's reasoning and improve a move through investigative talk and exchange of reasoning. Because the students were put in a situation where they have to justify their mathematical thinking to someone else (their teammate), it creates good conditions for them to jointly create an even stronger argument or find another way to solve the given problem (Whitenacke & Yackel, 2002). The configuration with both teammates and opponents thus allowed students to come up with new moves that were more advantageous to them by evaluating each other's reasoning. However, Othello being a game and a social situation it also created conflicting and inconsistent findings in terms of the students' reasoning. One was that we did not observe that students used a strategy inspired by reasoning of the opposing pair. One student expressed: '...The others shouldn't hear our plans.'. In this sense it should be considered that the competitive element of Othello can create limitations for the students when expressing their reasoning to each other. Another finding was that the number of 'unjustified and power claims' (Díez-Palomar & Olivé, 2015) such as 'Black has a lot of advantages', did not change notably over the six rounds of play. Here is another example of how these claims were observed in the interaction.

Student1: 'We could put it there.'

Student2: 'Yes, I think we should do that.'

Examples of power claims are: 'Yes, we are so smart, folks.' Or 'That's why we're winning.' The reason students used 'unjustified claims' and 'power arguments', which respectively correspond to 'Interaction type 1 and type 2', might be associated with the tendency of primary school students to use inappropriate forms of conversation as suggested by Díez-Palomar and Olivé (2015) and Larsen and Lindhardt (2019).

4.3 Principle three: Have the Students Play Specific Variations of the Game

Intention: As an integral part of the Othello activity, the teacher (and later, the students) can continuously try to change the premises of the game. This can be done, for example, by adjusting starting positions and letting students try out different game situations the students must start their game from. In this way, students are motivated to reason in new ways, which can contribute to their ability not only to apply specific strategies in specific situations, but also to understand why those strategies work (Houssart & Sams, 2008). This in turn requires the use of the 'if...then' formulations in new contexts, which further promotes their 'exploratory talk', if challenges are received positively (Mercer et al, 1999).

Analysis: By combining input from our contact from the Danish Othello Association, four young Othello talents and the rule book from Othello we chose four strategies as the basis for development of seven student worksheets. Each of these changed the game's premise offering different starting positions that we envisioned would encourage students to reason mathematically, Guiding questions and some of the worksheets formulated that the students should use 'if... then' in their response to the task. The worksheets were introduced from the second lesson. We observed how students started to plan more than one move ahead and predict the opponents' future moves which is crucial for formulating a winning strategy (Houssart & Sams, 2008). One example of this is:

Student: 'We're White, right? We start by putting one here, then we take the two. Then they put a Black one there and take them.'

The statement is an expression of a student considering not only how many pieces their move allows them to flip, but also how the move will affect their opponent's ability to flip pieces. This kind of reasoning was more frequent in the game rounds where the students played based on a worksheet.

5. Discussion

Inspired by McFeetors et al. (2018) we discuss three central arguments, each representing a distinct perspective on whether mathematical reasoning occurs when students explain and justify the claims they make in connection with the intervention.

Firstly, students used mathematical aspects in their considerations about the strategies they were introduced to in two different ways: By applying already acquired mathematical knowledge they have met earlier in school, and by using mathematical aspects they only occasionally had encountered in school previously thereby the students integrated mathematical aspects in both a retrospective and a forward-looking perspective. This included using knowledge of; diagonals and symmetry axes in connection with the worksheets, simple arithmetic by counting the number of pieces they could flip and, of the coordinate system when discussing the placement of pieces on the game board, as the playing board was divided vertically into the numbers 1-8 and horizontally into the letters a-h.

Secondly, if mathematical reasoning, among other things, involves generalization based on patterns (delMas, 2004), it can be argued that the strategies students develop during the intervention represent a form of generalization of the patterns they became familiar with in the game. Thus, we can claim that they are indeed engaged in a kind of mathematical reasoning.

Thirdly, we became aware of how reasoning mathematically about strategies in a board game is a communicative process. When students try to provide informal explanations and justifications for a claim in an engaging context that gives them a sense of continuous progression and coherence between their reasoning, it can be said that they are practicing the preliminary exercises for a more formal work with mathematical reasoning. For these three reasons, we argue that students articulated mathematical reasoning in their work with Othello.

Although we believe that students can present mathematical reasoning when playing Othello in an educational context where the three design principles are applied, we also acknowledge that our design has limitations. For instance, a student responded to something entirely different when the teacher asked a follow-up question meant to encourage reasoning, addressing whether the student had considered more than just her upcoming move:

> *Students: 'We used code words so the others wouldn't hear what we were thinking. Salad, relish, and stuff.'*

The response is aimed at concealing a strategy for the opponent which didn't encourage further mathematical discussion in the group. It indicates that the student did not understand that the aim of the lessons was to formulate correct and meaningful arguments for claims in the form of a reasoning. It could be because the students understand the activity as gameplay instead of mathematics (Jensen & Hanghøj, 2022). One issue with validating our results is the entanglement of the design principles when implemented (Hanghøj et al, 2022). It is difficult to pinpoint the exact impact of each principle when we successfully encourage the students to reason. The worksheets changed the game's premises through various setups but were also applied in pair vs. pair scenarios, even incorporating 'if... then' statements in some cases. This complexity makes it hard to assess each principle individually. As a result, we propose that it is the combined effect of the principles that contributes to the development of student reasoning.

6. Conclusion

In a DBR-approach we conducted a literature study of mathematical reasoning and the potential for analog games in developing this in primary school students. Using the potential of the board game Othello and the findings of the literature study we created three design principles. The principles are intended to be used by teachers to plan mathematics lesson aimed at promoting students' mathematical reasoning with Othello. We investigated the principles empirically through a teaching intervention in a fifth-grade math class. We found that students engaged in ‘exploratory talk’, which was demonstrated by the students presenting reasoning involving both structural and procedural aspects. The fact that students were able to engage in exploratory

talk during the Othello activities indicates that the intervention had potential for developing students' mathematical reasoning.

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Researching Game-Based Learning: A Brief Synthesis Project

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Abstract: The purpose of this research synthesis project is to survey existing digital game-based learning (DGBL) research in order to generate preliminary categories that articulate analytically distinguishable cognitive competencies. These include orientations, attitudes, interactions, and dispositions that enable cognitive development through playing games. We compile an initial literature scan, limiting the language to English, then search via keyword "game-based learning" through the following educational research databases: Eric, Education Source, Communication & Mass Media Complete, Education Index Retrospective, and Teach Reference Center. This returned over 1,500 results, which we refined by filtering out papers focused on gamification, those researching populations outside of educational contexts (e.g., private business and healthcare), systematic and scoping reviews, and papers published before 2010. This focused the results closer to 1,300 papers, which we divided into two categories, research focused on learning ecologies, and research using "motivation" in its key words and/or abstract. One clear and unexpected result was the way in which DGBL research inconsistently discusses motivation, and how it mainly seems to be used as a catch-all for measuring GBL outcomes. This brief synthesis reveals that much more attention needs to be paid to whether and how potentially pat constructs like motivation are being deployed in GBL studies.

Keywords: Game-based learning, Learning ecologies, Engagement, Motivation

1. Introduction

The following review of games and learning literature was not approached from the standpoint of "how can games support learning", or even from the standpoint of "how do games support subject matter understandings such as science or math or physics". Instead we interrogated the extant literature through a set of questions: 1) methodologically, what papers (if any) approach game play as part of the larger learning ecology of a classroom or learning 'event' and how do they describe their approach and outcomes?; and 2) definitionally, how do researchers describe and/or define what are largely non-measurable outcomes such as 'engagement' and 'motivation'? For both searches we used a variety of databases—PSYCH Info, ERIC, Communication and Mass Media Complete, and Education Index Retrospective. Search terms for the methodological question included "ecology and video games", "ecology, video games, and learning", "video games and ecology", and "digital games and ecology". For the definitional question we used a primary search category of "digital games and learning", refined by the secondary search terms "engagement" and "motivation". To better manage the scope of the search, we only examined articles and research reports from 2010 to June 2023.

The purpose of this paper is to review the literature related to both questions, with two aims: the first is to better understand how researchers are making use (or not) of an ecological approach to studying video games, and learning how that perspective might yield insight into optimal ways to carry out games and learning studies amidst the messiness that invariably accompanies classroom studies; the second is more prescriptive, attempting to better understand how researchers have defined, understood, and (where so claimed) measured 'motivation'. For the latter, although we had filtered out gamification studies as outside the frame of this review, a large number of gamification studies remained in the sample because their key words related to "game-based learning," and these papers had to be removed or retained on a case-by-case basis, according to their overall relevance to our key search criteria. What was included in the sample were all papers that explicitly addressed GBL, irrespective of methodology. While this yielded a large number of papers, we wanted to take the broadest approach possible in this initial pass at the literature review. In the next two sections, we detail what each separate search yielded, expanding, where relevant, extended summaries of key papers in the areas.

2. Ecologies of Learning With Video Games

It is not the intent of this literature review to rehearse the research on media ecologies or, by extension, learning ecologies, except to point out that an ecological approach to studying learning has been around for quite some time (Klopfer, 2011), and has been used as a methodology to better understand the intricacies of learning environments. Learning ecologies are used to broadly refer to the whole system of teaching and learning: social, cultural, tools, technologies, curriculum, time, space, and their network of inter-relations (c.f. Barron, 2006; Lave

& Wenger, 1991; Lemke, 2000; Jackson, 2013). A learning ecology, then, can incorporate both formal instruction and curriculum and informal learning opportunities outside of classrooms.

In the literature on video games and learning that we reviewed there is limited, if any, engagement with learning ecologies as a theoretical or methodological framework for research on the topic. In general, there were three lines of inquiry that made use of the concept of 'ecology'. The first looks at ecologies within the games, that is games that contain their own ecologies such as plants, animals, and ecological systems, that act on players, just as they are acting and enacted upon by a digital game. For example, Sheu explores a fishing game, *Brass Pro Shops: The Strike*, to explore how the game mimics real world ecologies of bass fishing, and another paper examined player preferences in *World of Warcraft* related to areas in the game, finding that most preferred vegetation-based landscapes (Truong et al., 2018). Another ecologically focused view on video games is made in Alenda Chang's book *Playing Nature* (2019). Chang argues that video games and their depictions of nature and environment, including the ways that players interact with (or largely do not), can challenge players to think differently about the virtual environments they inhabit, reflecting also on 'real life' counterparts. As Chang puts it: "games can offer a compelling way to reconcile a deep connection to nature and the non-human world with an equally important connection to technology and the virtual" (p. 5).

The second line of inquiry, like the first, looks specifically at what ecologies are present or enacted by the game system, environment, rule structures, and actions. This asks what 'ecologies' are present (real or imagined) in the game, and a few papers go so far as to ask questions about what might be learned by interacting with those in-game ecologies. For example, *Red Dead Redemption* (RDR) and its follow-up title *Read Dead Redemption 2* (RDR2) are commercial video games set in the colonizing period of the American West. The game features flora, fauna, and wildlife endemic to the region during the time the game is set (roughly late 1800s) that can be interacted with and that interact with the player as they explore this open-world game. Crowley et al. (2021) set out to study whether players who had and players who had not previously played RDR2 were able to correctly identify species depicted in the game. Overall, they found that playing RDR2 supported correct visual species identification, and that interaction, even simulated with the overall ecology of the game world, resulted in player observation of programmed animal behaviours most players would not have had access to in the real world. In a similar virtual world to the real world identification study, Coroller and Flinois (2023), examined whether players of *Animal Crossing* were better at species identification from the game than non-players. Overall, they found that playing *Animal Crossing* (AC) contributed to players obtaining higher scores on identification quizzes than non-players, suggesting that players "learned the name of the organisms and became able to recognize them, despite having likely never encountered them in real life" (p. 12). And in another study of *Animal Crossing*, Ho et al. (2022) surveyed over 600 players, and found that playing AC contributed to greater understandings of limited resources, such as trees and water.

The third application 'ecology' to video games is more centrally about digital games as and through a learning ecologies framework. While outside the scope of the search parameters for this review, it is important to acknowledge an edited collection by Katie Salen Tekinbas (2008) entitled *The Ecology of Games: Connecting Youth, Games, and Learning*. Interestingly, the concept of ecology in this text is taken loosely to refer to the ways in which games might contribute to new literacies, new practices, and new socio-cultural forms for young people. While the concept of ecology (beyond the introduction) is under-interrogated in the edited collection, it does at least serve as a touch point for entering into thinking about playing and interacting with digital games as learning ecologies.

More recent literature that mentions digital games as potential learning ecologies is still scant, and our rather exhaustive searching only produced 5 papers that directly address the topic. The first paper has learning ecologies in its title and directly addresses how digital games are increasingly a part of learning ecologies (Persico et al., 2019). The authors claim (as we do) that there is a paucity of research on digital games as part of larger learning ecologies, suggesting that this omission in part results from a focus on a single game and/or single learning environment (formal or informal), rather than adopting the wider perspective afforded by a learning ecology lens. Data for the study was collected through interviews and focus groups with key stakeholders: teachers, parents, players, game developers, and GBL researchers. Analysis of the focus group and interviews is broken out into recommendations for each of those stakeholder groups, binarized into "positive and negative aspects" of using digital games for learning. In the end, the possibilities for understanding digital games as part of formal or informal learning ecologies is left behind, as there is no 'ecological' focus present in either the data collection or the analysis. In the end, Persico, et al. (2019) argue:

> *Our study has investigated some positive and negative aspects of digital gaming for learning from the point of view of the main actors who play a role in the LE [learning environment]. The results demonstrate how important it is that all actors in the landscape are fully aware of the salient characteristics of this ecology component to harness its promise for learning in all contexts. (p. 1700)*

Klopfer (2011) takes a similar stance, which is to rather under-define what learning ecologies look like when playing digital games. This is all well and good when your research does not necessitate a more detailed description of the ecologies in question, but just what are those ecologies? What do they look and feel like? How do we identify, understand them and study them?

A second paper examines the home gameplay practices of one adult individual (Vazquez-Calvo, 2018) over a six-month period. The paper is mainly concerned with documenting the variety of literacies the individual practices through his gameplay and fan-related engagements online, including translation from English to Spanish. The author does spend some time documenting the ecology of their informant's literacy practices as a fan and game player, but this examination is not followed through into the conclusion, leaving the paper more as a literacies mapping exercise than a specific focus on learning ecologies.

A third paper focuses on GBL and second language learning through an ecological approach to 'gaming' (Ibrahim, 2017). The author defines an ecological approach to L2 learning by focusing on the "actions, processes, and relations" (Ibrahim, 2017, p. 535) of the learner in a given setting. The paper reports on 6 English speakers interested in learning Egyptian Arabic, who are asked to play a resource management game, *Baalty*. Data collection included a think-aloud protocol that participants used to document their gameplay as well as a pre-study questionnaire to collect data about previous gameplay experience, screencasts of video gameplay that recorded both their gameplay and the think-aloud activities, game logs, game journals, fieldnotes, and semi-structured interviews. It seems an enormous amount of data was generated from these 6 L2 language students, which contributed to the primary finding that those participants with either a higher L2 proficiency or previous gameplay experience tended to "make limited use of the opportunities for practicing new L2 discourse" (Ibrahim, 2017, p. 543). However, those more limited in L2 or gameplay experience were challenged by and interacted more with the linguistic affordances of the game. While the author claims to have taken an ecological approach to both study design and analysis, it is not made clear how the ecology of the game (or "gaming ecology") actually figured in the study's conclusions.

A final study flips the attention from the students to the teachers, asking how teachers implement an educationally focused math game across 4 different classroom ecologies. Data collection included video recordings of teachers and students during the implementation of the game as well as pre- and post-tests, and informal interviews with teachers after the game implementation days. The authors analyze and report on the study through 4 cases involving 4 different teachers. While they do cursorily describe the ecology of the classroom, this does not figure largely in their cases. Rather, the authors argue that "teachers are a central part of the overall learning ecology that develops around the game" and that "students learn better and have more opportunities to engage with the mathematics content of digital games if teachers interact with students and talk about the math during gameplay" (Bell & Gresalfi, 2017, p. 86). In other words, if teachers understand and are involved in talking about the game and its play, students tended to do better on the post-test in this study.

Overall, the literature on GBL and learning ecologies is sparse and under-developed, which is interesting considering that an ecological approach to studying GBL might well help to move the literature out of the realm of "it depends" onto firmer ground. It is the case that there is a growing area of work that examines the particular ecologies in video games as having possible implications for understanding 'real world' ecologies, however there really is not much written to date on that. Taking a broader ecological approach to GPL might document "just playing" within the context of a classroom, including both how things stay the same and how the simple act of playing might change the classroom's learning environment.

3. A "Motivation" Industry?

It shouldn't be surprising that 'motivation' figures largely in outcomes related to game-based learning. However, the sheer number of papers with claims related to motivation, and the massive variation within the literature on how 'motivation' is understood and reported became a surprising outcome of this review. The full sample of game-based learning articles was over 1,400 papers, and of those a search within abstracts and keywords yielded 537 papers that had 'motivation' as part of their titles, keywords, or abstracts. Each was individually assessed by the first author, first at the level of abstract, and then, where the relevance proved high enough, the full paper was reviewed. Overall, 120 papers were reviewed in full. Papers potentially relevant that turned out to be

gamification studies were, as previously indicated, left out of this analysis. Also removed from the analysis were health and exercise game studies, studies focused solely on flow theory (Csikszentmihalyi, 1975), and largely generic GBL studies that might for example mention "motivation" once in the paper in a literature review, but without interrogating the concept further, nor reporting on results related to that construct.

We found that "motivation" is a construct that is surprisingly widely used, yet not necessarily well defined or even understood in many of the GBL articles we reviewed. For example, are games motivating learning or are the researchers reporting on being motivated to continue to play the game? What are the boundaries for motivation (i.e., how do you see it, measure it, and report on it (some studies do this, others do not), and how is motivation different from engagement and attention? Overall, we noticed a pattern in these papers that could be characterized as falling into three broad categories: 1) papers that used motivation as a kind of 'straw' construct invoked in title, keywords, abstract, and maybe a literature section, but that then does not figure in the analysis, results or conclusion of the paper; 2) papers that go some way towards trying to say what they mean by motivation (most often taken to mean intrinsic motivation see section 3.2) attempt through a self-report (survey or questionnaire) to collect data on the construct, and report some results and conclusions on any motivation indicated therein; and 3) papers that were all quantitative, were careful to define what they meant by attention, and then reported on those results. These studies often referenced large data sets, created their own instruments, and reported both positive and null outcomes related to GBL and motivation. As these latter cases exceed the scope of this brief review we will concentrate on cases 1 and 2.

3.1 Vaguely, Motivation

While it is not possible to review each and every paper that was included in this first category of using an ill-defined construct in relation to motivation, here we will endeavour to present some explicit examples of this issue through a closer look at three representative papers. First, though, it is important to know that much of the GBL literature begins in a very similar place, attributing the "motivational" properties of video games to the likes of Prensky (2001) and Gee (2007). Neither of these two oft-cited books are empirical; written a significant time ago relative to the rapidly-evolving landscape of videogames, they are simply waxing poetic about the learning possibilities for digital games. That the current crop of literature reviewed here still chooses to harken back to those early days, especially in relation to the motivation inspired through playing games, is somewhat suspect, given how much games have evolved since the early-mid 2000s.

The papers detailed next were chosen randomly from a larger sample of 25 papers categorized as loosely defining (if at all) "motivation". The first is a paper that looks at GBL and Chinese poetry learning (Chen & Lin, 2015). The authors argue that playing a game "increase motivation" and (citing Prensky, 2001) can create entertainment and pleasure. Motivation in the paper is described as "learning motivation", which was measured via a scale from a questionnaire about the willingness to play the game based on Chinese language poetry. Results from the study indicated that the students who were in the experimental group (i.e., game playing) were more motivated to learn Chinese poetry than those in the control group (non-game playing). It is not made clear what 'learning motivation' is per se, nor how a self-reported questionnaire could capture that construct.

Paper 2, "Narrative categorization in digital game-based learning: Engagement, motivation and learning" (Breien & Wasson, 2021) examines those three constructs, "engagement, motivation and learning", through a review of 14 papers that discuss 15 digital GBL games, or "systems" as the authors refer to them. These authors also start with citing Prensky (2001), before moving on to argue that games have been found to be both motivating and engaging in well cited literature reviews (e.g., Clark et al., 2016; Connolley et al., 2012; Novack, 2015). While the term "motivation" comes up 44 times via a key word search, it is never explicitly defined, but the paper makes clear that it refers to being motivated to keep playing the games being reviewed. It also often appeared alongside 'engagement' and 'learning', terms we found frequently being used interchangeably with 'motivation'.

Paper 3 takes another kind of—equally vague—approach to the concept of motivation (Tsai et al., 2012), once again citing Prensky (2001) and Gee (2003) to shore up its argument that the study of games and learning is a relevant to education. In this paper, the term "learning motivation" surfaces once more. While it is also not concretely defined, its use in this instance appears to be related to motivation to learn about the subject area (energy saving). There is an important distinction made in the paper between "learning motivation" "to seriously learn new knowledge" and "playing motivation" which is just the motivation to stay in the game or keep playing. Overall, this study of 8 players found that being more motivated by playing the game than by the desire to learn more about the subject the game was built around (energy saving) meant there was less overall understanding of how to save energy. It is not clear how precisely this motivation (either playing or learning) was measured, what the researchers meant by that concept, or how it connects to other similar research.

In another example of a paper that uses the term motivation (albeit in a very limited manner), Cîrnu et al. (2012) argue for the potential of commercial games for learning. One small part of that argument is that games are universally (or so it seems) motivating. They too, inevitably, cite Prensky (2005) whom they quote as arguing that games "have goals that give motivation" (p. 322). That is really the extent of their argument, and the rest of the paper contends in favour of using a few different commercial games in learning contexts.

Finally, Dickey's (2011) work explores how a narratively driven, adventure style game, *Murder on Grimm Isle,* might impact "intrinsic motivation", "curiosity", "plausibility" and "transference of game-based experiences" (p. 456). Unlike Cirnu et al., Dickey never defines what "intrinsic motivation" is, although it's claimed there is a form of it within the game design, whereby players are able to choose which way to go at the start of the game, and the authors argue in their discussion that preconceived notions of what a 'game' is might impact different players, making them more or less motivated to play. Unsurprisingly, this study too cites both Prensky (2001) and Gee (2003) as part of the argument for why and how games are useful as learning tools.

Overall, and with of course some variation, the papers in this category were using motivation as a taken-for-granted construct that is linked (almost always positively) to playing games irrespective of game type, duration, or design. What these papers make clear is that there is quite a lot of work to do in becoming clear about what motivation entails in relation to learning and games.

3.2 Motivation as a Central Construct

Papers that centred motivation in a GBL study were also quite common, varied in their approaches and outcomes, and took few steps towards even superficially unpacking what they mean by motivation. This was the second largest group of papers (66) in this review. Again, we have chosen to describe 3 papers that are representative of those papers that, despite having 'motivation' as a central construct, do not necessarily interrogate or clearly define it.

Cornille et al. (2012) describe a study on corrective feedback through a game for English language learners. They choose to use a game to support language learners through a Computer-Assisted Language Learning (CALL) framework, which, simply put, means that they are using language learning games on computers to support second language acquisition. They too rely on Prensky (2001) to make the case for learning through playing games and propose that the immediate feedback loop of a game makes it naturally suited and useful for language learning. They loosely define motivation in game design terms, that is the push-pull between positive reinforcement and negative reinforcement, such that the player isn't deterred from "successfully completing an action or a task" (Cornillie et al., 2012, p. 260). They then go on to discuss how motivation (intrinsic and extrinsic, neither construct being unpacked or well-defined) is impacted by corrective feedback and vice versa in the literature on second language acquisition and CALL. Motivation is linked directly to corrective feedback and its potential impacts on L2 language learners, and that carries through their study of 83 language learners playing a role-playing game in English. The researchers created a series of questionnaires pre- and post-play and in-game to measure motivation, supplemented by interviews with participants. They argue that in the end, "intrinsic motivation" is contributed to by positive and adaptive feedback in the game. While they do define intrinsic motivation as "an individual's subjective experience that is the combined result of enjoyable immersive gameplay with his or her positive perception of competence as the result of play" (p. 273), it isn't clear precisely how that subjective experience is accounted for directly by the data collected. Moreover, construing 'intrinsic motivation' as contributed to by 'positive feedback' is a dubious move conceptually, since intrinsic motivation is 'endogenous', it comes by definition from 'within' the subject and cannot therefore be the result of external ('exogenous') factors like reward, punishment or any other goal "extrinsic" to the activity.

Next, Zhang et al. (2021) study a role-playing game they designed to support university students' understandings of information literacy. Motivation in their study was reviewed in relation to GBL as one part of a kind of "learning" package that included engagement, persistence, and flow. Motivation is never defined, nor is there a distinction made between intrinsic or extrinsic motivation, except Insofar as the instrumentused was adapted from Wang and Chen (2010) and assigned 3 questions to each type of motivation in the pre- and post-surveys. As a central construct that was evaluated in the study through a pre- and post-survey of 90 participants, it was found that they were more motivated when playing the collaborative and competitive versions of the game versus solo play, and in their discussion it becomes a little clearer that the authors mean 'motivation to learn' when writing about 'learning motivation' (Zhang et al., 2021, p. 164). While this paper never defines motivation, authors are approaching that construct through a limited range of prior literature on the topic.

Finally, Chen and colleagues (2015) looked at solitary versus collaborative gameplay with 50 seventh grade students who played a science-focused game, which was designed by the researchers to reinforce key science concepts such as force and equilibrium. The authors go to some lengths to review the related literature on GBL, including its treatment of motivation, and they quasi-define motivation as motivation to learn, i.e. to learn about the science concepts, not to keep playing the game. They also make use of an instrument that has measures for both intrinsic and extrinsic motivation, which they administered both prior to and after gameplay. Unlike the Zhang et al. (2021) study, this paper did not report any difference between collaborative and solo play in relation to the motivation measures. They did, however, show improvements from pre- to post-test after playing the game.

What is difficult to really apprehend in any of the three above studies is what exactly is being identified and assessed in terms of motivation—most importantly, are we looking at motivation to play games generally, or to play just the game being studied, to explore that game's environment, to persist in playing it, or to learn about the academically relevant subject it encapsulates? And how is that motivation to play being identified and measured? Or are we looking at motivation as either an observed or a self-reported interest in learning something, or as an observed engagement in persisting with further learning? In either case what is the relationship between self-reports of being 'motivated' and observations of playing behaviours? Of no less importance, where engagement, attention, persistence and motivation are all used seemingly interchangeably, how are these and cognate terms to be distinguished conceptually, as surely they must be, and then operationally, within the studies themselves? All of this really does need to be unpacked, and yet these and the vast majority of studies we reviewed both rely upon the concept of motivation and invoke it is as a black box, even as they attempt to measure and report on it.

4. Next Steps and Conclusions

What is primarily clear from this partial and ongoing review is what GBL research does *not* do: important theoretical and methodological ideas and practices that inform recent and current scholarship in other fields and forms of inquiry— new materialism for example— have made almost no inroads into the field of GLB research and scholarship, which thereby risks becoming stagnant. There is a lot more care and attention that can be taken in GBL research and practice to attend to the wider learning ecologies in which GBL studies take place, through careful qualitative inquiry capable of engaging with current and emerging theories and research practices. It is paramount that GBL studies begin to take a serious look at 'motivation' as a construct that has been and continues to be among its most frequently invoked concepts, and yet remains inadequately—if at all—elucidated, and with rare exceptions (ref) almost completely undertheorized. The idea of motivation in GBL studies is instead rehearsed in a pop-psychology rendition that conflates it with a host of other cognate 'good things', such as engagement and 'flow', interest and attention, and despite decades of careful critical analysis of the concept to draw upon from the fields of philosophy, psychology, and more recently neuroscience.

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Assessing Creative Awareness and Literary Writing Games in the Norwegian Context

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Abstract: This paper reports on a survey and teaching intervention done with Norwegian students in their first (VG1), second (VG2), and third year (VG3) of high school English (16-19 years old). The goals of the project: 1. To examine Norwegian student/teacher attitudes toward creativity; 2. To design, play-test, and asses creative reading games. The study found students surprisingly open to creativity and games in education, however, there was a general wariness of assessment. As the students progressed through high school, they increasingly saw writing as something one is forced to do, and resisted sharing their writing. Almost all students saw themselves as outside the community of writers. While the novel nature of the games made for initial difficulties, this was also a motivator. The key to effectiveness was pairing theory with practice to give students a clear sense of the pedagogical goal: to develop and experience the use of creativity (divergent thinking). The use of multimodality in games (drawing) was immensely effective for student engagement and collaboration; however, it was less effective in terms of maintaining clear pedagogical goals in the time given. Finally, the most effective approach in terms of engagement was to involve students as game designers. This paper will focus on a presentation of student views on creativity followed by an assessment of the game results in light of these views.

Keywords: Games, Creativity, Teaching, Divergent thinking, Critical reading, English

1. Introduction

Divergent Thinking and Creativity: A Brief Definition

Creativity studies has placed divergent thinking at the center of creativity measurement and critical discussion. In short, divergent thinking is the mind's ability to create ideas by multiplying possible connections. Convergent thinking, on the other hand, is the ability to narrow down connections to a single "best" solution/connection. A simple way to think of divergent thinking is fluency (quantity produced) in forming surprising associations or creating interpretations from a single shape/text. A typical example from the most influential creativity test (Torrance, 1966) might be to present a series of identical circles and see how many individual drawings can be produced. A textual question might look like this: How many uses can you think of for a toothpick? While there is significant depth to this research area, including detailed ways to measure creative results, this basic definition will suffice in this context.

Many contemporary thinkers see creativity as central to society (Urban, 2007) (Enquist et al, 2008), and it is a commonplace in the digital era to see the creative model of thinking as more valuable than the encyclopedic model. Rhodes made this claim over half a century ago (1961), and it seems only more evident in an age where individuals must increasingly adapt to changes in society (Runco, 2004). As there is general agreement that intelligence is increasing in society (Kim, 2011), it would seem society is well prepared to excel in creative thinking; however, this is not the case. Creativity actually seems to be in decline (Kim, 2011).

While creativity studies have blossomed in the last decades (Corazza et al, 2022), creativity is still generally misunderstood. The designer of the most influential creativity test pointed this out long ago (Torrance, 1962). While researchers had repeatedly debunked creativity myths, the myths remained fixed in the popular mind (Rhodes, 1961). This continues as we see creatives marginalized in the classroom (Beghetto, 2007), find them categorized as disruptive forces (Torrance, 1962) (Beghetto, 2007) (Amabile, 2018), and face a public discussion of creativity framed by these myths. The most prevalent of these myths are that only certain people are creative, creativity cannot be taught, creativity is not useful, and creativity cannot be assessed (Treffinger, Isaksen, and Dorval, 2000) (Amabile, 2018) (Guilford, 1950).

Despite these myths, a variety of tools have been developed to increase creativity, from Alex Osborn who invented brainstorming in the 1950s (Baer and Kaufman, 2012), to Peter Elbow's seminal work on freewriting (1986), to Torrance's extensive work on divergent thinking (term explained below), including the most influential creativity test, the Torrance Test of Creative Thinking (Torrance, 1962) (TTCT; Torrance, 1966).

Motivating environments have also been studied extensively. Game environments have repeatedly proven to increase engagement (Bowman, 2018), and there has been extensive work done on collaborative environments, from indexing collaborative writing approaches (Lowry et al, 2004), to arguments that reveal collaboration hindering creativity as much as encouraging it (Zhang, 2022); however, environments without

judgment are the determining factor in successful motivation, as has been shown extensively in studies by Amabile (1982, 2018) and supported by other researchers (Baer and Kaufman, 2012) (Beghetto, 2007).

Finally, the seemingly avant-garde use of chance associations in the creative process has recently shown great promise (Ross and Vallé-Tourangeau, 2021) (Mastria et al, 2022). In these studies, disconnected or distracting information infuses divergent thinking patterns into the creative process and triggers concrete gains in creative solutions.

While these pieces of the creativity puzzle have been explored, we have yet to study what happens when we combine these successes into a pedagogical approach aimed at critical reading and writing, particularly in the Norwegian context. This study assessed student and teacher views of creativity, then examined the potential of *game-based*, *collaborative*, *association-based, divergent-thinking* activities to create an understanding of creativity skills and to motivate a prolonged engagement in reading and thinking critically about literary texts.

Research questions:

RQ1. How open is the Norwegian high school environment to creativity?. 1

RQ2. Can divergent-thinking writing games motivate creativity and engagement in critical reading?

The project had four phases:

- First, student attitudes toward creativity were explored through a pre-game survey and discussion.
- Second, brainstorming and freewriting tools were used to train students in the theory and practice of divergent thinking.
- Third, a game-based approach was used to explore motivation, the effectiveness of collaboration, and the usefulness of association (both chance and directed) as a method to motivate in-depth, interactive, and critical reading.
- Finally, two comparisons were made:
    - multimodality (drawing) games versus purely textual games.
    - a teacher-driven game-based approach versus a student-as-game-designer approach.

2. The Study

Over the course of three months in the spring semester of 2022, the researcher conducted preliminary observations, a survey, a three-class teaching intervention (4.5 hours total), and verbal and written feedback sessions with 66 Norwegian high school students in first year (VG1: 31 students), second year (VG2: 18 students), and third year (VG3: 17 students) English classes (ages 16-19). The teaching intervention included discussion, game-testing sessions, and feedback sessions. The data collected included passive and active (teaching) observation, teacher interviews and discussion, a student survey that included written feedback and discussion, game results, games developed by students, and a series of post-activity questionnaires for student feedback and evaluation of the process and the games.

Pre-Game Questionnaire

The pre-game questionnaire (see figure 1) was administered to 66 students (VG1:31/VG2:18/VG3:17) and focused on five areas of inquiry:

1. Exploring students' relationship to the myth of the exclusivity of creativity (questions 6 and 7).
2. Measuring student self-identification as "logical"/math-based thinkers vs. "creative" thinkers (questions 1 and 10).
3. Assessing student views on the importance of creativity/games in education (questions 2, 6, and 8).
4. Identifying students' relationship to professional/serious creativity (inclusion/exclusion) (questions 3, 5, and 7).
5. Determining the level of collaboration students have experienced (questions 4 and 9).

		1	2	3	4	5	
1	I love numbers						I love writing
2	Games aren't important for learning						Games are very important for learning
3	I know a writer personally						I don't know any writers
4	I don't like sharing my writing						I love sharing my writing

		1	2	3	4	5	
5	I see myself in stories I read						I don't see myself in stories I read
6	Inspiration cannot be taught						Inspiration can be taught
7	Poets are like everyone else						Poets are special people
8	Creativity isn't a serious school subject						Creativity is as important as math in school
9	I usually write alone						I usually write in a group
10	I like clear answers						I like creative answers

Figure 1: Pre-Game questionnaire

Students were asked to rank themselves on the spectrum from 1-5. After filling out the survey, there was a half hour full-class discussion as well as written feedback. The written feedback questions were as follows:

- How do you see yourself in terms of creativity?
- Even if you aren't creative, what's a creative thing you have done?

The goal of these two questions was to contextualize student answers and to discover what things beyond writing (the focus of the questionnaire) students saw as creative.

Expectations based on creativity myths: 1. Boys would self-define as loving numbers over writing, with girls the opposite; 2. Students overall would see games as unimportant for learning; 3. Students would be outside the community of writers; 4. Students would be extremely wary of sharing their work and would rarely have worked collaboratively; 5. Students would see inspiration as something special that cannot be taught and poets/writers as special, naturally gifted people; 6. Students would prefer "clear" answers over "creative" ones. 7. Students would see only art as creative.

Pre-Game Questionnaire: Results

Surprisingly, the pregame questionnaire found that both boys and girls in this sample see creativity and games as important for learning, especially in their second and third year; however, this view of creativity was disconnected from school writing, and almost all students saw themselves as outside the community of writers. As students progressed through school, they increasingly saw writing as something one is forced to do, and increasingly resisted sharing their writing. At the same time, a majority of students thought inspiration/creativity was a necessary and teachable skill, and this belief increased as students progressed. Thus, students saw creativity as a key to their education, but they did not associate this goal with school or school writing. Finally, a significant number of students saw creativity as a risk when linked to assessment.

Pre-Game Questionnaire: Quantitative Data and Discussion

The graph below represents scores averaged for all students, (decimals rounded up at .5). Note that higher numbers signify movement toward one answer on the spectrum. See detailed data below the graph.

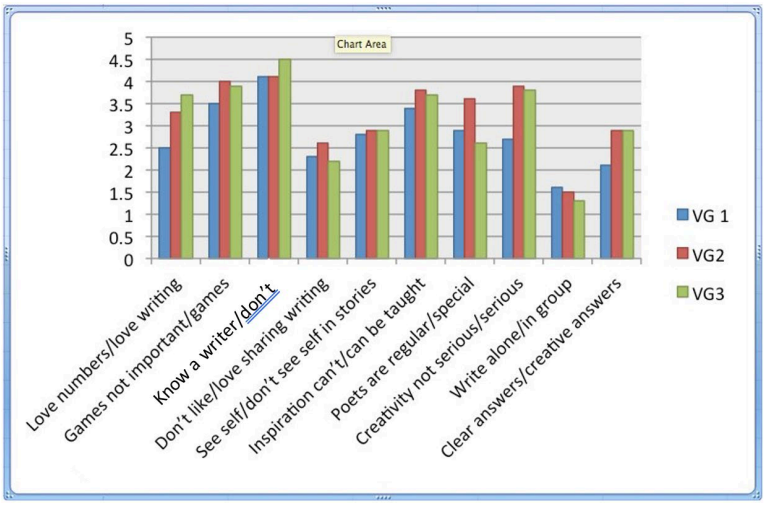

Figure 2: Pre-Game questionnaire answers for all students

The detailed scores below are listed as follows: VG1 → VG2 → VG3.

1. Love numbers/love writing: 2.5 → 3.3 → 3.7
    a. Notice the clear increase as students progress VG1 to VG3. English is required in VG 1 and selected in VG 2 and 3, which may affect the data on interest moving from VG 1 to 2.
    b. In VG 1, girls (3.2) were significantly more interested in writing than boys (1.8).
2. Games not important/games important: 3.5 → 4→ 3.9
    a. Importance of games increased as students progressed.
    b. Overall boys saw games as more important than girls.
        i. Girls: 3.3 → 3.8 → 3.8
        ii. Boys: 4→ 4.3 → 4.4
3. Don't know a writer/know a writer: 4.1 → 4.1 → 4.5
    a. In discussion, it was revealed only a single student knew a writer (1.5%).
    b. 100% of the students knew an engineer.
4. Don't like/love sharing writing: 2.3 → 2.6 → 2.2
    a. This was closer to the middle than projected.
    b. Note: the word "love" is used rarely in Norway and is considered an absurd exaggeration.
5. See self/don't see self in stories: 2.8 → 2.9 → 2.9
    a. Girls see selves *less* in stories as progress to VG3: (2.7 → 2.7 → 3.1)
    b. Boys see selves *more* in stories as progress (3.2 → 3.1 → 2.6)
    c. This is a large topic that merits more detailed inquiry.
6. Inspiration can't/can be taught: 3.4 → 3.8 → 3.7
    a. Overall students saw inspiration as highly teachable. This was a surprise for the researcher when compared to research on creative myths and decades of teaching observation. This may partially be the influence of Norway's pragmatic, egalitarian ("Janteloven") culture.
7. Poets are regular/special: 2.9 → 3.6 → 2.6
    a. VG2 class scored significantly higher than the other classes, especially the boys.
        i. VG2: girls: 3.5; boys: 3.8.
    b. This seems contradictory as VG2 boys also scored highest on "inspiration can be taught". It seems logical that if poets are special/different, this is natural as opposed to taught. However, the VG2 score still sits in the middle range (3), so it is only high when assuming that creative myths, studied mostly in the U.S., hold true in Norway. Creativity myths merit a wider quantitative survey across Norway.
8. Creativity not serious in school/as important as math: 2.7 → 3.9 → 3.8
    a. There was a significant increase across the board as students progressed.
    b. Note these surprisingly radical comments on this question from the qualitative feedback:
        i. VG2 boy: "Creativity is useful in every job, and throughout life, whereas math is only in some career paths."
        ii. VG2 girl: "Since not everyone likes math and wants to work with math later in life, people should be able to learn about something else that's not useless for their future."
9. Write alone/in group: 1.6 → 1.5 → 1.3
    a. Scores and discussion showed little collaborative or group writing, save for a few involved in "sequential single-author writing", in which writing is divided and involves a minimal amount of interaction (Lowry, Curtis, and Lowry, 2004).
10. Clear answers/creative answers: 2.1 → 2.9 → 2.9
    a. There was a general movement toward creative answers, though this question was a bit of a trick question to elicit student challenge of this dichotomy in discussion. One VG2 student did challenge it in written feedback and discussion.
        i. VG 2 boy: "…why do you separate logic and creativity when the most creative solutions come from logical thinking?"
    b. There was a clear movement toward creative answers for boys: 1.5 → 2.6 → 3
    c. Note that there was a lack of clarity on this question's relationship to assessment, the major creativity killer. Fear of assessment may account for the low scores. However, as shown below, when a majority of students self-identify as not-creative, creative tasks may not initially motivate them.

Feedback Questions

1. How do you see yourself in terms of creativity? (only clear answers of "creative"/"not creative" were counted; students writing "in the middle" gave .5 points to each side):
    a. Clearly see self as creative: VG 1 → VG 2 → VG 3
        i. Notice boys increase and girls drop *significantly* in their self-evaluation as creative.
            1. All:
                - 59% → 44% → 41%
            2. Girls:
                - 67% → 40% → 36%
            3. Boys:
                - 27% → 50% → 50%
2. Ranked list of top things students sees as creative (number of students listing a topic):
    a. VG1: art (7), writing (6), food (3).
    b. VG2: stories (3), drawing (2).
    c. VG3: art (5), writing (5), music (3), dancing (2), food (2).
        i. Note that in each class, students held traditional/reductive notions of creative activity. Research in the U.S. reveals that students overwhelmingly see creativity as pertaining solely to art (Treffinger, Schoonover and Selby, 2021). Food appeared as the only surprise here.
    d. This restricted notion of creativity can negatively affects motivation and self-identificaiton, as the VG2 girl below notes:
        i. "I think I can in some ways be creative, but I feel like it is hard for me to be creative in the sense of what others make, for example poems, movies, stories etc."
    e. However, when forced by the question, students named an extensive list of creative activities: VG1 (14), VG2 (25), VG3 (24). The leap after VG1 suggests that self-identifying "creative" students select English over other subjects.

Qualitative Data VG1

1. Creativity as "childish"
    a. 21% of VG1 students associated creativity with childhood; however, zero students self-identifying as creative felt this way.
3. Creativity and motivation/assessment
    b. The fear of assessment as a detriment to creativity was quite marked in discussion and feedback:
        i. VG1 student (NA gender): "I would say I am creative, but school doesn't really grade you for creativity."
        ii. VG1 student (NA gender): "I can be sometimes (when I'm not forced to be)."

Qualitative Data VG2

1. Creativity as disruptive/"childish"
    a. In discussion and in the written results, this was evident. For example, one student wrote a poem on sex that, while appropriate to the task, could challenge many teaching environments. The following comments also demonstrate how creative spaces can instigate provocative topics:
        i. VG2 boy on creative activities:
            1. "I built a homemade bong for vaping, from a soda can."
            2. "I'm creative in a way that I'm really good at lying on the spot, finding ways to do less work."
    b. Students at all levels gave feedback that creativity was neither taught nor encouraged at school except in childhood. Here is a VG2 girl who self-identified as not creative:
        i. "I am more able to be creative on my spare time, than at school."
2. Motivation and creativity
    a. Extensive research and practice has found motivation as a key to creativity (Baer and Kaufman, 2012) (Amabile, 1982, 2018) (Glaveanu, 2017). Student comments reflected this.

i. VG2 boy: “I see myself creative when I’m having fun or if I’m interested in whatever I’m doing. While I am bored I usually don’t care so much, which is the reason why I’m not creative.”

Qualitative Data VG3

1. Creativity as “childish”
    a. This VG3 girl noted the embarrassment surrounding creativity due to judgment and the sense that creativity is childish/disruptive.
        i. “I loved to write when I was younger. I often made up stories, but the interest disappeared as I grew older. Me and [female friend] also had a blog and Youtube account, but that's embarrassing.”
2. Motivation and creativity
    a. Students felt that school does not connect skills to creativity, which lessens motivation. Note this VG3 boy’s view:
        i. “I see myself as a bit over average creative, but usually feel like I don't have the skills to utilize it.”
    b. However, this VG3 girl argues that mandatory creativity lessens motivation, though it may stem from fear of assessment:
        i. “I…find it difficult to be creative when I'm being forced to do so.”
    c. This VG3 girl echoes these sentiments and connects them to creativity as “childish”:
        i. “I think I used to when I was little. Maybe 'til I turned 14. But the pressure of school has turned every type of creative work into something that has to be done.”

3. Pre-Game Teacher Feedback on the use of Creative Games

All three teachers saw establishing a “free” (non-judgmental) space as fundamental for developing student writing, and each had previously tried versions of free or semi-free writing with some success. At the same time, all three named sharing as a challenge to this free space, both in the past and as something expected in the games. Peter Elbow calls the management of this tension between open supportive spaces and assessment “embracing contraries” and sees it as key writing pedagogy (1986). The VG1 teacher noted that this lack of freedom was internalized, especially with her more advanced students who “seem to censor their writing”, particularly in the early stages. Despite valuing this freedom, the VG3 teacher noted that the pressure of exams and curriculum left little time for “this kind of work”. Thus, even a teacher who sees the importance of creative pedagogy does not feel she has the tools to integrate it.

All three teachers hoped the games would help students develop more creative writing practices. The questionnaire mirrored this need, showing that as students progressed, they self-identified as increasingly less creative. Before the questionnaire, the VG3 teacher noted that her students mostly self-identified as “not creative” and argued that this set up a nervousness about success that, in turn, affected interest in creative activities. While the myth of creativity as a “childish” endeavor was present in all levels of the questionnaire, of the three teachers, only the VG3 teacher specifically noted this. She added to this that the absence of a creative view of writing was detrimental to student success: “The students start as creative and curious writers in first grade and end up finding writing a struggle by the time they come to upper secondary school.” All three teachers foresaw clearly explaining the goals and rationale of the games to students as a possible challenge, a sign of the novelty of the approach and the disconnect between students and creative practice.

4. Pre-Game Creativity Training

The interventions were done in succession (VG3, VG1, V2) so that the approach could be tested, improved, and compared. While the games at each level were different (geared to the texts and needs of each individual teacher), the pre-game training was the same series of divergent skill builders. This training also functioned to clarify pedagogical goals, something the study found fundamental to building student motivation.

An exploration of freewriting types was used as a divergent thinking/writing skill builder and also to clarify the goals of the games. First a spectrum was explained running from divergent thinking (explained as the creative/writer part of the brain that loves to create/write and doesn’t judge) and convergent thinking (the judge/editor who assesses what has been created). Then a series of freewriting exercises (not in this order) were used to explore this notion, including the notion of chance as a tool in divergent thinking, something “word bomb” did with surprisingly successful results in terms of motivation. Note to users: the only rule in

basic freewriting is that a practitioner cannot stop. One student simply wrote potato repeatedly. This radical openness is necessary to open a non-judgmental space.

- Freewriting with eyes closed (most divergent on the spectrum)
- Freewriting with random word ("word bomb") dropped in (divergent + chance association)
- Freewriting (middle divergent)
- Freewriting with trigger phrase "I remember" (most convergent, as memory directs it)

These activities were successful motivators, but there was considerable improvement in their use in the games as each iteration simplified/clarified the concepts represented. The terms divergent/convergent were termed too specialized, so in the first iteration (VG3) the term "creativity" was used. Creativity myths undermined the specialized use of this term, so in the second iteration (VG1), "reading like a writer" was used. This was even less successful, so in the third iteration (VG2), "creative mind" was used. This was the most effective in clarifying for students that the goal was to motivate them to understand and develop divergent thinking. Each iteration also increasingly centered students as game testers and designers which improved student motivation.

5. Textual Game Mechanics

The study found that most of the game mechanics were more useful for teachers designing games than for students. Here is the original list presented to students:

- **Juxtaposition:** finding the connection between distant terms.
- **Erasure:** erasing part of a text to make new meaning**.**
- **Replacement:** replacing parts of a text to explore new meanings.
- **Reordering:** reordering a text to explore possible meanings.

After the first two iterations (VG3 and VG1), it was clear this list created an unmanageable cognitive load for students. "Juxtaposition" was the only mechanic deemed useful for student exploration and study, as it was the central game mechanic and most clearly connected to divergent mechanisms. In divergent thinking, the stranger a juxtaposition (increased distance between the terms in the analogy), the more flexible and original it is, in other words, more creative (Baer et al, 2012). As the pursuit of this strangeness/distance seemed inappropriate to students at first, it was key to explain how this represented "creative mind". This distance then became an acceptable goal. This was particularly effective as it provided a clear overarching goal for games that did not Test Well.

Game one: Replacement (VG3)

The teacher selected Olive Senior's poem "Colonial Girls' School" as part of a unit on postcolonialism. A key to replacement work is use the form of the original to help students create new juxtapositions in their own rewrite. As Senior's poem was semi-formal, the researcher paired it with John Agard's formal, postcolonial poem "Flag" and students built an analogy poem using both sources. They then compared their use of the term to Senior's use. As the original poem was very serious and provocative, the replacement ended up exploring issues of racism, sex, language, body image, and alcohol use.

Game Two: Multimodal Reordering (VG1)

In this game the teacher picked two stories, Ernest Hemingway's "The Killers" and Leslie Marmon Silko's "Tony's Story". The class was split in two teams to index one of the stories into major events, draw these events, then trade the drawings with the other team. The other team used the drawings to invent a story, then the original and invented stories were compared. While this game motivated the students and encouraged creative storytelling, the time spent on drawing meant less time for attention to the original text, the final comparison, and a clear exploration of how this represented divergent thinking.

Game Three: Analogy Riddle (VG2)

This was the most successful game in terms of engagement, collaboration, and the use of juxtaposition as a tool in critical reading and thinking. The teacher chose Hemingway's "Hills Like White Elephants", and students selected two terms, one unknown to their audience. The student then wrote a riddle of five associational clues that lead to the unknown term. Students ran their game through three play-tests with different students, modifying clues each time. Students continued to play after the bell, one even chasing the researcher down to play. This game asked students to find commonalities between two terms in the text. This ability to pursue

analogies is at the heart of the critical reading we do in literary studies. The game also asked students to explore their own relationship and understanding of the terms they took from the text. Exploring this relationship is a key method for helping students position themselves in terms of the text and also sits at the heart of creating a critical relationship to the text. Finally, the iterative game-testing created an emphasis on audience and revision that are key skills in critical writing.

6. Conclusions

Students across the board found freewriting engaging and as the concept of "creative mind" was clarified students were increasingly able to connect the divergent thinking goals established in freewriting to the games themselves. Overall, the students enjoyed the novelty and freedom of the games, however, students had trouble seeing the point of some of the games without this clarification of "creative mind" as an overarching goal. This demonstrates the usefulness of including students in pedagogical theory. Teaching the game mechanics was too complex, but they were useful as tools to develop and revise the games. This is promising as it represents a concrete set of tools for the teachers, who all wrote that they wanted creative teaching tools. While the multimodal approach moved students away from reading the text as closely as the other games, it did succeed in creating high interactivity between teams, collaboration within teams, and confident student sharing of stories. As teachers identified sharing as a major obstacle to establishing a creative space, this aspect of the multimodal approach shows much promise. Overall, the "analogy riddle" game was the most engaging due to the student investment as game designers and the iterative testing that created collaboration, engagement, and made it the most interactive of the games. It also created the most critical thinking about the original text, as students had to find creative connections between two terms, a skill at the heart of close reading and critical thinking. In other words, creating a game by comparing two terms in the text pushed students to think deeply about the terms' meanings in the text, in relationship to each other, and in relationship to the student themselves. This critical positioning of a term is vital as students advance in their critical thinking about texts. In future research, it would be useful to try these games on the same text and compare student results to see how they differ in producing divergent thinking, engagement, and in-depth reading/critical thinking.

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Implementation of Game-Based Learning in a Tertiary General Education Course

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Abstract: Game-based learning can be an entertaining, engaging, and effective way of learning if both the game-play experience and educational content were carefully designed and balanced. By modifying an existing commercially available game rather than developing a game from scratch, the technical side and entertainment aspect of the game can be guaranteed so that educators can spend less effort in the technologies and game design but focus more on the educational and pedagogical aspect of designing and implementing game-based learning. We have enhanced a popular commercial computer game, Civilization, for use in a general education course that aims to nurture scientific literacy for tertiary students. The game has been used as a learning and assessment tool for this course along with other traditional course activities. The enhanced game includes scenarios which simulate world history and requires the players to lead a civilization and compete in these scenarios. Playing this 'mod' allows students to reflect upon, among many interesting issues, the dependency of scientific development on the political, economic, cultural, and geographical factors in history, which is one of the important intended learning outcomes in our course. The game has been used for 5 consecutive academic years. Survey responses and academic grades have been collected and analysed. The result is positive in both the rating on enjoyment and indicators of effectiveness of learning. Students who played the game are more engaged in course content, more willing to attend lectures and received a better course grade at the end as compared to those who didn't. While we cannot simply conclude with a causal relationship based on our reported analysis, we believe that playing this game is useful and suitable in complementing our traditional pedagogy. The engagement in game playing will increase, not decrease, students' effort spent on other traditional course activities.

Keywords: Game-Based Learning (GBL), Commercial-off-the-shelf (COTS), Civilization, Tertiary education, General education

1. Introduction

Game-based learning (GBL) is an educational approach that uses game content and game play as a pedagogy to achieve certain learning outcomes (Plass et al., 2015). Typically, GBL involves the design and use of an educational video game to support teaching and learning within a curriculum together with other traditional pedagogies (Perrotta et al., 2013; Shaffer et al., 2005). These games are sometimes considered as serious games with their primary goal being more than just pure entertainment (Michael & Chen, 2006), including the promotion of learning, attitude and behaviour change through playing (Dimitriadou et al., 2021; López et al., 2021).

GBL requires to strike a balance of covering the subject matter and prioritizing game play (Plass et al., 2015). By overcoming the challenges in the game, it provides learners with a sense of achievement while at the same time serving educational purposes. To achieve this balance, a good game design is necessary to make video games "fun", in the extent that games are neither too easy nor too challenging, so players do not feel bored or frustrated during playing (Admiraal et al., 2011). Game settings such as incentive system, game aesthetics, story narrative and game music are all important to keep players' interest in a game (Gee, 2003; Squire, 2013).

These games can facilitate three types of learning outcomes. The first is the development of specific knowledge, skills, and abilities (Kapp, 2012). Second, learners can also apply subject content to simulated real-world issues and develop generic skills, such as problem-solving skills, under the interactive nature of serious games (Dimitriadou et al., 2021). Third, GBL can promote positive changes in attitude, behaviour and emotions towards the course content (Sandí-Delgado et al., 2022). For achieving these learning outcomes, GBL should be designed in accordance with contemporary learning theories with a successful game design (Qian & Clark, 2016; Young et al., 2012). The theories can be explained in three major perspectives correspondingly, namely cognitive, sociocultural and behaviour/motivational perspectives (Plass et al., 2015).

Cognitively, learning from video games is mediated by engaging appropriate cognitive processes to shape cognitive development and learning (Tobias & Fletcher, 2014). Playing can be considered as a learning environment that is motivating yet lots of information is to be processed by the learner. The process provides gamers with repeated opportunities to practice skills and apply knowledge, ending up transferring knowledge from the game to reality (Plass et al., 2015). More educational games are developed with a view to learning in an interactive means for knowledge acquisition (Perrotta et al, 2013).

Good educational game allows players to enter the cognitive state of "flow" (Csikszentmihalyi, 1990; Plass et al., 2015). Flow is a concept from positive psychology which brings players to the intense, sustained and focused engagement to achieve a goal with pure pleasure rather than external rewards. Players attain a state of concentration to focus on the activity, which can be achieved with moderately challenging tasks and instant feedback (Nakamura & Csikszentmihalyi, 2014). Players in the state of flow are beneficial to talent development and academic performance while at the same time meaningfully engaged in the learning process (Csikszentmihalyi, 1990; Coller & Shernoff, 2009). The state of flow creates the optimal experience for individuals to master their skills and engage themselves in the activities (Csikszentmihalyi, 1990). To achieve flow, Csikszentmihalyi proposed that there are eight elements as the conditions: A challenging but tractable task to be completed; one is fully immersed in the task; one feels fully in control; one has complete freedom to concentrate on the task; the task has clear unambiguous goals; one receives immediate feedback on actions; one becomes less conscious of the passage of time; sense of identity lessens, but is afterward reinforced, which are common among people with optimal experiences, and these eight elements can be achieved in educational games to guide players entering into the state of flow (Cowley et al., 2008).

From the sociocultural perspective, video games provide rich contextual information and social interactions that improve learners' understanding of social norms and emotional recognition (Plass et al., 2015). Students can develop a comprehensive understanding of the world from different angles under role-playing simulating games (Squire, 2005). Also, by closely mirroring real life or simulating a scenario, learning can take place in a socially and culturally structured virtual world by providing information to the learners at the precise moment, to exercise their problem-solving skills to some of the simulated real-life issues (Plass et al., 2015). Acquisition of soft skills such as collaboration, problem-solving, imagination and creativity are all present in video games, as many of the multi-player games require high order thinking skills to overcome the challenges and achieve the final goal (Yang, 2012). There can be wins and losses in video games, yet video games allow graceful failure as the lowered consequences of failures in games encourage risk taking, skills development and receiving positive feedback, so players are more motivated to continue exploring new things (Plass et al., 2015; Hoffman & Nadelson, 2010). Failure is sometimes expected and designed as a way for players to reflect on their strategies, thinking how to overcome the challenges to achieve a specific learning goal, in turn learning from their mistakes and facilitating the learning process (Kapur, 2008). The role-playing nature of many video games also allows learners to explore various social roles inside and outside of the game, forming new ideas and testing them to develop independent thinking (Squire, 2005). Learners can immerse themselves in a setting highly resembled the real world, easily setting up a learning community and transforming learning from the stage of "learning by being told and doing" to "learning by playing a role and becoming one" (Twining, 2009; Qian & Clark, 2016).

Motivationally, well-designed video games also stimulate players to engage in the learning process and to focus better on studies than traditional learning approaches (Dickey, 2005; Whitton, 2011). These video games are capable of engaging and motivating players by providing experiences they enjoy; thus, they are eager to continue the interaction (Gee, 2003; Krath et al., 2021). With the same rationale, educational games motivate players to pay close attention to game details, fostering their cognitive processing of the contents and thereby improving learning.

GBL could also lead to greater student engagement and participation in other course activities if implemented correctly. A positive influence on lecture attendance has been observed as students found the gamified course content more interesting and motivating to learn (Barata et al., 2013). Sailer & Homner (2020) performed a meta-analysis to statistically synthesize the existing research on the effects of gamification on cognitive, motivational, and behavioural learning outcomes, with positive findings as well.

2. Methodology

We shall now explain how we adopt GBL in a tertiary general education course that the author of this paper taught for the last 10 years. This course, called "In Dialogue with Nature", is one of the two seminar courses in the General Education Foundation Program, which is a common core requirement for all undergraduates in the Chinese University of Hong Kong. The course is concurrently taught by 13-14 lecturers. Each lecturer teaches around 150 students in each semester. This course aims to nurture students' scientific literacy and requires students to read excerpts of many science-related classics as core texts (Chan et al., 2012). One of the core questions in this course is to discuss the so-called "Needham's grand question", which can be phrased as "why had modern science not developed in Chinese civilization?" (Needham, 2004). While there is unlikely a direct answer to this question (Sivin, 2005), reflecting upon the historical settings, dependencies of scientific

development and scientific revolution allow students to have a more comprehensive understanding of what science really is.

The course has been well received by the students (indicated in the course evaluations conducted in each semester) for it being intellectually stimulating. However, students often find the core readings in this course challenging and difficult to comprehend. They also find it hard to situate themselves in the respective worldviews of the core texts. These could be due to the lack of reading confidence, insufficient understanding of background knowledge and the difficulty of visualizing the complex historical setting. Considering this, several e-learning tools were developed to assist students in this course (Kiang et al., 2016). In particular, a popular commercial game called Civilization (version 4 and subsequently 5) was adopted for GBL by the author, as one of the lecturers in this course, for his own class.

2.1 Commercial Off-The-Shell (COTS)

It should be noted that developing a sophisticated game that can achieve all the effects mentioned in the introduction is not an easy task. We avoided developing from scratch and have investigated the possibility of adopting commercial off-the-shelf (COTS) game at the beginning. COTS games are created by companies for entertainment purposes. These companies usually would know better than teachers on how to make an effective and engaging game to attract players (Van Eck, 2009; Charsky & Mins, 2008). While these games were not designed for educational purposes, a commercial game can still be used if it is designed to be a serious game, which usually provides intellectual challenges or rich in contents (Charsky & Mins, 2008). The most popular approach to using COTS games for education is to enhance the existing game with more specific educational content using the tools provided by the game. This is the most cost-effective in terms of money and time and maximizes the quality of the game used (Van Eck, 2006). COTS games cover a wide range of areas like math (e.g., the Sims series), history (e.g., Civilization), or science (e.g., Contraptions). The challenging nature of the COTS games also teaches students problem-solving skills if they play these games over long periods of time (Van Eck, 2009).

Built on the above concepts, the author has selected the game Civilization for GBL in In Dialogue with Nature. The game Civilization is a world simulator. A player can lead a chosen civilization starting from 4000 BC until 2050 AD to compete with other civilizations for land and resources and develop one's own civilization into a scientific, military, religious or cultural leader in the world. We think that this game provides enough opportunities and challenges to allow students to enjoy, enter the state of "flow", exercise their critical thinking and learn from their mistakes. We have purchased 200 game licenses (first in Civilization 4, and then subsequently Civilization 5) and obtained the written consensus from Firaxis (the company which developed the game Civilization) to allow students in each semester to use the licenses for the educational purposes mentioned in this paper.

The author has modified the game (using mostly the development tools that comes with the game) include adding two new scenarios that simulate the geographical landscape of the real world (plain world map starting at 4000 BC) and the historical setting in 1500 AD. Playing this 'mod' allows students to reflect upon, among many interesting issues, the dependency of scientific development on the political, economic, cultural, and geographical factors in history, which is one of the important intended learning outcomes in our course. We also asked our students to play the 1500AD scenario twice, once as a Western civilization and once as an Eastern civilization, so that he/she can compare their scientific development to generate their own reflection on the Needham's question. The "mod" for Civilization 5 is made publicly available on Steam, a widely popular gaming platform, for everyone to use (Kiang, 2018).

Playing the game is structured as an optional assessment as it may not be the cup of tea for all students (Whitton, 2011). Students can freely decide whether they want to play the game or to participate in online written discussions facilitated by Blackboard discussion forums. Both options are structured under the assessment component called "outside-class student participation", which is worth 10% in the assessment scheme of this course. The other assessment components in this course are in-class participation (16%), quizzes (24%), and essay writings (50%). We shall now present the evaluation results of this GBL implementation in the next section.

3. Evaluation and Discussion

3.1 Students' Perception of GBL

Students' opinions towards the two learning activities, namely playing the game Civilization and Blackboard online discussion, have been collected via surveys for five consecutive academic years (from 2016-17 to 2020-

21)[1]. There are in total 1111 student respondents, with 485 students participated in online discussions and 626 students experienced GBL in this course. In general, feedback from the students about these learning activities is generally positive, with all the survey items scoring higher than 3, the neutral rating of the 5-point Likert scale used (Table 1). By comparing the two groups, independent-sample T tests are conducted, determining if there is any statistical significance between the population means of the two groups. The scale of $p < 0.05$ is used to indicate any statistical significance observed.

The data shows that the game is considered a more effective learning tool, as more student respondents agreed that it increases their interest in course issues (game = 3.99, discussion = 3.33), helps students understand fundamental concepts in the course (game = 3.87, discussion = 3.56), is enjoyable to participate in the activity (game = 4.20, discussion = 3.64), is helping in learning (game = 3.94, discussion =3.69) and is convenient for students to join (game = 4.24, discussion = 4.01) (Table 1). Playing games as a learning activity revealed itself to be a more popular and enjoyable one for students.

Table 1: Students' satisfaction with learning activities (Mean value in a 5-point Likert scale)

Survey item	Game	Online Discussion
[The activity] increases my interest in course issues*	3.99	3.33
[The activity] help me understand fundamental concept in the course*	3.87	3.56
Overall, participating in [the activity] is enjoyable*	4.20	3.64
Overall, participating in [the activity] is helpful in learning*	3.94	3.69
The current setting for [the activity] is convenient*	4.24	4.01

* $p<0.05$ for the two-group comparison under two-tailed t-test

In parallel with the student surveys, focus group interviews have also been conducted in the first academic year (2016-17) in the 5-year period. Students' verbal comments related to the games reinforced the above quantitative findings. In general, student respondents stated that the game-based learning experience inspired them to think about the course materials and connect what they had learned. Representative quotes are listed below (originally recorded in Cantonese, translated to English by the authors):

> *"The game allows me to re-evaluate my thoughts on civilization development, and I started to realize the importance of several factors, such as scientific progress and population growth, that are crucial for the prosperity of countries."*
>
> *"Through playing the game, we can observe how a civilization develops and their scientific development at any given time frame. As scientific research grows slower in some countries, this echoes the viewpoint from the text that science may not develop well in every civilization."*
>
> *"By playing the game, I realized that there are weaknesses in certain civilizations that hinder their development as reflected in history. This part tells me more about the importance of science in the history of humanity."*
>
> *"When I was reading the required text about the scientific development of China, I did not have any clues about the impacts on people's daily lives, and it is hard to compare the scientific progress of different countries. From the game, I discovered that the Western civilizations have the edge over China in terms of scientific progress, leading to the early modernization of the Western countries."*
>
> *"The game provided a great chance to become aware of issues a state leader has to deal with, such as resolving the shortage of food, addressing citizens' needs, and preventing the overthrow of the government. Economic problems and military threats are the top priorities for state leaders."*
>
> *"In order to win the game, we have to actively reflect on their development strategy, figuring out the possible reasons that some civilizations are underdeveloped, and the solution to it. Such a thinking practice can nurture our critical thinking and problem-solving skills."*

[1] The data for the first semester of 2019-2020 academic year is missing due to the social unrest in Hong Kong.

3.2 Self-Perceived Attainments of Learning Outcomes

We also would like to measure how GBL contributes to students' attainment in the course as a whole. Instead of directly asking questions about the game or the online discussions, we have also asked several questions related to the course learning outcomes, but NOT specifically related to either of the two outside class activities. Comparing the results from the two groups shows that the game group gave higher ratings in self-perceived attainments of the learning outcomes in this course (in a 6-point Likert scale). These include: their interest in natural science (game = 4.57, discussion = 4.37), acceptance in scientific knowledge as important for their intellectual development (game = 4.89, discussion = 4.73), understanding the development in natural science (game = 4.60, discussion = 4.48), understanding features of scientific methods (game = 4.74, discussion = 4.61) and understanding the contributions and limitations of scientific inquiry (game = 4.81, discussion = 4.71) (Table 2).

Table 2: Students' self-perceived attainments (Mean value in a 6-point Likert scale)

Survey item	Game	Online Discussion
I am interested in natural science*	4.57	4.37
Scientific knowledge is important for my intellectual development*	4.89	4.73
I understand the development of natural science*	4.60	4.48
I understand various features of scientific methods*	4.74	4.61
I understand the contributions and limitations of scientific inquiry*	4.81	4.71

* $p<0.05$ for the two-group comparison under two-tailed t-test

3.3 Objective Evaluation - Course Grade

Apart from collecting evidence about students' interest and self-perceived attainments, we have also collected and analysed their course grades as an objective evaluation in their attainments. Our findings indicate that students choosing to play the game as their learning activity performed better than those choosing online discussion, with their course grade points (e.g. A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, etc) being 3.236 and 3.180, respectively (Table 3).

To avoid the doubt of self-selection bias (i.e. better students select to play the game), we put these grade points under a benchmark. We collected and deducted the students cumulative grade point average (cGPA) in their previous studies in the university before taking this course. This allows us to have a proxy to measure only the "gain" in grade point in this course, assuming students would otherwise obtain their usual performance in this course. Interestingly, the cGPA of the game group scores lower than the discussion group on average, 3.120 and 3.175 respectively. By deducting the grade point in this course by their cGPA, there is a 0.116 grade point gain in the game group while there is negligible grade point gain (0.005) in the discussion group. The difference of the two is statistically significant. This result seems to suggest that GBL is effective to lift students' academic performance in this course, as compared to using written online discussion, a more traditional pedagogy.

Table 3: Students' academic performance

Survey item	Game	Online Discussion
Students' course grade (over 4)	3.236	3.180
Students' cGPA before enrolling the course (over 4)*	3.120	3.175
Course grade – cGPA*	0.116	0.005

* $p<0.05$ for the two-group comparison under two-tailed t-test

3.4 Course Engagement

A typical challenge raised against GBL is that playing games might easily distracted students from their "proper" coursework. While this also relates to the stigmatization of playing games as "time wasting" or "not educational", it is still a legitimate worry whether playing the game would compensate their time in other learning activities. Table 4 presents the relevant survey data in this regard. Our finding shows that, students

spent significantly more time playing the game than those in the online discussions (game = 10.41 hours, discussion = 4.41 hours). However, students in the game group spent a similar amount of time (no statistical significant difference) on course reading (game = 2.37 hours, discussion = 2.40 hours) and writing reflective journals (game = 7.28 hours, discussion = 7.19 hours). Moreover, the attendance rates of lectures (game = 71.3%, discussion = 69.7%) and tutorials (game = 84.9%, discussion = 86.2%) for both groups are also similar, indicating that spending more time playing the game does not necessarily deter students from other learning activities in this course. It is suggested that when students are more motivated to learn, they would be more willing to spend time in the course. Hence, using GBL together with traditional learning activities may not be a zero-sum game. If students find the game interesting, they would compensate more of their leisure time voluntarily to the course, rather than necessarily giving up in other learning activities.

Table 4: Students' lesson participation rate and efforts spent on different learning activities

Survey item	Game	Online Discussion
Hours spent on game or discussion*	10.41	4.41
Hours spent on reading each required course text	2.37	2.40
Hours spent on writing each reflective journal	7.28	7.19
Lecture attendance	71.3%	69.7%
Tutorial attendance	84.9%	86.2%

* $p<0.05$ for the two-group comparison under two-tailed t-test

4. Conclusion

GBL can be beneficial to education if implemented carefully. A good balanced educational game can facilitate students' development of specific knowledge, generic skills and improve their motivation in course learning. We have reported our implementation of GBL, using the COTS game Civilization, in a tertiary general education course. We modified the game using mainly the tools provided by the game to enhance the aspects related to the specific knowledge of this course. Students can optionally choose between playing this game or participating in online discussion as an assessment component. Results showed that for those who participated in the game enjoyed the game more than those participated in online discussion. The game group also rated higher in their self-assessed achievement towards the course learning outcomes. More importantly, the objective evaluation via grade point analysis showed that the game group performed better than the discussion group. There was a significant difference in the time they spend on the two activities, but there was no significant difference in their time spent on other course activities (lecture and tutorial attendance, time spent on reading and writing). While we cannot simply conclude with a causal relationship based on our reported analysis, we believe that playing this game is useful and suitable in complementing our traditional pedagogy in this course. The engagement in game playing will not decrease students' effort spent on other traditional course activities. It is hoped that our findings highlighted the effectiveness of GBL in helping students to learn and arousing their interests in tertiary education.

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The Effects of Gamifying Mathematics Lessons at High School Level

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Abstract: Gamification encompasses the utilization of "playful" or "game-like" elements within non-gaming contexts. It finds diverse applications, primarily within the realms of education/training and the workplace, with the aim of enhancing teamwork and productivity. Nonetheless, the concept of gamification remains a topic of significant debate. Several authors caution that gamification may undermine intrinsic motivation to learn or perform, particularly among younger audiences. Furthermore, the research community increasingly emphasizes potential negative consequences resulting from specific gamification mechanics, such as competition. In this article, we present an approach to gamification that combines competitive elements, albeit at the level of student groups rather than individuals. The idea is to minimize the exposure of underperforming individuals while capitalizing on collaborative group dynamics, wherein stronger students provide support to weaker ones. We conducted a quasi-experiment, comparing motivation and performance between a gamified classroom scenario and a conventional, non-gamified scenario. The results indicate that the proposed gamification approach boosts motivation and performance in contrast to the non-gamified condition. These findings contribute to a deeper comprehension of the effects of gamification and offer a realistic perspective on its beneficial impacts within educational settings

Keywords: Gamification, Mathematics, Motivation, Performance, Competition, Collaboration

1. Introduction

Gamification has become a ubiquitous element of our digital culture. One stumbles across elements of gamification in all domains, ranging from advertisements to work assignments. It is not surprising that the gamification of education has been in the interest of many researchers and developers. The fundamental idea is that learners at all levels of education, from primary school to workplace training would need some sort of extrinsic motivation to learn, respectively to learn better, for a longer period of time, with more focus, and so on. The fundamental solution to the challenge of providing extrinsic motivation is to enrich conventional learning settings or learning tools with certain elements of play and gaming. This solution, however, is subject of substantial debate. On the one hand, authors like Ian Bogust (2015) criticize gamification as marketing point and highlight that in many cases, it's not about the "game" but about the "-ification", indicating the poor and superficial integration of overly simple and meaningless game elements such as getting scores and badges for "primary features like interactions with behavioral complexity". Other authors warn about the potential detrimental effects of reward tasks and behaviors. Alfie Kohn (2018), for example, elaborates on negative impact of not providing additional rewards for certain tasks, once learners or users are accustomed to these rewards. On the other hand, the gaming and in particular the serious gaming community often considers gamification as a half-hearted, desultory attempt to make certain tasks fun. They criticize that gamification reduces the enormous potential, meaning, and the spirit of games to simple, repeatable elements in which "benefit, honor, and aesthetics are less important than facility" (Bogust, 2015). Initiatives that attempt to push and ensure the quality of serious games, for example the German quality certificate for serious games (ral-seriousgames.org), which is based on the DIN Serious Games elements meta data standard (DIN SPEC 91380:2018-06), deliberately excludes gamification as a certifiable application or product. In turn, the proponents of gamification certainly have a point. Learning, especially in formal learning settings such as schools, is not necessarily a fun and exciting task. In many domains, subjects, and topics learners don't have an intrinsic reason to learn or they at least believe not to have a reason. Oftentimes, learning is simple drill and practice, boring, and hard. The hypothesis that adding elements of motivation and fun, adding reasons to perform certain (learning) tasks, appears reasonable and justifiable.

In educational environments, the primary aim of gamification is to enhance learners' motivation, engagement, concentration, and potentially reduce frustration, ultimately leading to improved learning performance (Oliveira et al., 2023). Numerous studies have explored the impact of gamification applications in education. However, it is common for these studies to yield insignificant positive effects of gamification usage (e.g., Koivisto & Hamari, 2019). Furthermore, research on gamification often lacks clear and methodologically sound reporting of learning gains. Literature reviews by Oliveira et al. (2023), Nah et al. (2014), and Fadhli (2020) further support the notion that the effects of gamification remain unclear and vary across different studies. Nah et al. (2014) conclude that the investigation of gamification's impact is still in its early stages. In other words, we do not yet fully understand how different types of gamification work for different types of learners and in various situations. Oliveira et al.

(2023) suggest that personalization is a key factor for successful gamification implementation. However, a deeper understanding of gamification and its perception by learners is still needed, along with improved gamification design that positively influences learning performance (Rapp et al., 2019). Another critical aspect often inadequately addressed in gamification is the ethical challenges associated with its use. It is important to identify and characterize different gamification mechanics and types. Nadi-Ravandi and Batooli (2022), in a literature review, compile a list of commonly used gamification mechanics and elements. The most frequently reported mechanics and elements in the literature include points/scores, leaderboards/rankings, badges, progress indicators, graphical enhancements (e.g., avatars), unlocking new areas/levels/functions, rewards/prizes, and narrative elements. Essentially, there are different types of gamification: (i) mechanics that promote direct competition with others (e.g., leaderboards), (ii) a comparison with others or standards, and (iii) aesthetic enhancements. While type (iii) appears unproblematic, types (i) and (ii) are associated with the notion of comparing one's abilities to others. This can work well for high achievers but may have negative emotional and social effects on low performers, as they may constantly face reminders of their perceived inadequacy. Additionally, a significant group of learners may not be interested in any form of competition. Ethical concerns surrounding gamification are increasingly being addressed in research (e.g., Goethe & Palmquist, 2020; Kriz, Kikkawa, & Sugiura, 2022; Mazarakis, 2021). However, resolving these issues and achieving ethically unproblematic gamification implementation remains challenging.

In our current study, we present a conceptualized gamification scenario for the classroom. While gamification in typical e-learning applications has been widely investigated, gamifying a lecture within a regular classroom setting has received limited attention in the past. The target audience for the proposed scenario is 17 to 20-year-olds. Importantly, we have conceptualized a gamification scenario that harnesses the motivational power of competition while simultaneously mitigating potential adverse effects on low-performing individuals.

2. The Mathiade Gamification Scenario

Among the most commonly used mechanics in gamification are leaderboards, points, and badges (Oliveira et al., 2023; Yang et al., 2022). Thus, we have chosen to incorporate these mechanics into our gamification scenario. Additionally, we are utilizing a less explored and applied element of gamification, which is cooperation.

In educational settings, leaderboards represent rankings of learners based on measurable variables such as performance, achievements, diligence, and perseverance (Nebel et al., 2016). These leaderboards compare individuals' variables with those of their peers, creating a competitive environment. Competition is considered a fundamental element of games and play, aimed at motivating learners to persist in performing certain tasks. As pointed out by Landers et al. (2017), the presence of leaderboard leaders can provide others with a desirable goal to strive for, encouraging them to keep up with the leaders. This goal can enhance performance by directing attention, improving motivation and persistence, and promoting the use of goal-oriented strategies (Locke & Latham, 2002). Another less noticeable feature of leaderboards is that the comparison with others, such as classmates, provides criterial feedback. This feedback helps learners reflect on the connection between their individual effort and performance (Mekler et al., 2017). Yang et al. (2022) provide further detailed insights into how leaderboards affect learning. Schlömmer, Spiess, and Schlögl (2022) evaluated the effects of leaderboard positions on learners' immediate perception of stress, measured, for example, through heart rate variability. This allows us to incorporate this gamification element into our scenario.

The second gamification element in our scenario is cooperation. Cooperation can be viewed as a behavior facilitated by gamification (Riar, 2020; Riar et al., 2022), but it can also be considered a game mechanic in its own right (Erikson & Sammons-Lohse, 2021). Cooperation occurs when two or more individuals work together towards a common goal, where the actions of individuals positively influence goal attainment. Cooperation fosters the exchange of ideas, knowledge, and skills, while also influencing psychological variables and sentiments such as group norms and social identity. These factors, in turn, enhance motivation, engagement, and perseverance (Reza Keramati & Gillies, 2022). Extensive research has been conducted on the beneficial effects of cooperative learning (Johnson & Johnson, 2009).

Our gamification scenario, Mathiade, is designed for an entire mathematics lesson within a classroom setting. It combines competition and cooperation, both of which are expected to enhance performance. First, the teacher arranges students into groups of three or four, ensuring a balanced mix of stronger and weaker students as well as highly and less communicative students. The groups compete for points by solving mathematics tasks through an online interface (Fig. 1). Although each student works individually, they can see the live results (completed tasks and points) of other group members within the interface. With the aim of winning the competition, collaboration and mutual assistance among group members, especially the high performers and those with

competitive characteristics, are encouraged. The mode of communication and collaboration among students is flexible. On a central screen in the classroom, students can view the live rankings of the groups (Fig. 2) without individual performance information. By providing a public ranking through the group leaderboard, we aim to reduce the exposure and potential stigmatization of low performers, thus alleviating stress and other detrimental social and emotional effects on individuals. The interface has been implemented using HTML 5 as a browser-based app. Dynamic functions, such as task display, scoring, live results display, and data storage, have been implemented with PHP and JavaScript. The backend relies on a mySQL database. The application includes an item pool, the student interface, the group leaderboard, and additional administrative functions.

Figure 1: Screenshots of the Mathiade app

3. Study Implementation

To explore the impacts of implementing gamification in a classroom lesson, we introduced Mathiade to the 10th grade students at a secondary school in Switzerland. Our aim was to assess whether the gamification scenario led to enhanced task performance and motivation, in comparison to a control group that did not experience gamification. It's important to note that the variable "performance" in this study does not solely refer to improvements in mathematical skills, but rather serves as an indicator of motivation, engagement, and particularly effort. Additionally, we examined potential gender differences and the contrasting outcomes between high and low performers. Moreover, we investigated whether the gamification scenario promoted collaborative group work and communication, specifically analyzing whether stronger students provided support to their weaker peers. For our study design, we opted for a quasi-experimental approach involving both a treatment group and a control group.

3.1 Participants

A total of 43 students took part in the research project. We recruited four classes from a 10th grade in a secondary school in Liechtenstein, with each class consisting of 10 to 12 students. The average age of the students was 17 years. To conduct the study, the class teacher organized heterogeneous groups of 2 to 4 students, taking into consideration their varying levels of performance and openness. Due to practical considerations, we allocated the students from each class to either the control group or the experimental group.

3.2 Procedure and Materials

All classroom activities were conducted by the regular class teacher, who received instructions on the procedures and maintaining systematic logs of collaborative events during the lessons. Initially, we conducted a baseline survey on student motivation. One week later, we implemented the mathematics competition scenario, with one group experiencing gamification and another group serving as the control group. After an additional week, we repeated the scenario while switching the control and experimental groups. During the mathematics competition, students were given a strict time limit of 30 minutes. Both groups were allowed to communicate and collaborate within their respective groups, although it was not explicitly required. Immediately after each session, we administered the motivation questionnaire again. Throughout the sessions, teachers recorded any relevant events, specifically focusing on collaborative activities.

The motivation questionnaire items were based on a specific questionnaire developed for the educational context of gamification (Sailer, 2016, 171-174). This questionnaire encompassed four dimensions of motivation related to gamification: social integration (Cronbach's $\alpha = 0.86$), experience of autonomy in terms of contributing to tasks ($\alpha = 0.76$), autonomy in decision-making ($\alpha = 0.81$), and a sense of capability ($\alpha = 0.72$). The questionnaire comprised a total of 13 items, utilizing a 7-point Likert scale for scoring.

For the mathematics competition, we created a set of 120 test items covering fraction arithmetic. The items included basic arithmetic operations such as addition, subtraction, multiplication, and division. Dividends and divisors were either integers or fractions. Examples of items include 5 + 3/8, 7/9 - 8, and 6/12 * 7/24. Students had to enter their answers in text fields as either integers or fractions (Fig. 2). In the control group, students completed the tasks using a traditional paper-pencil format. They were instructed to answer as many items as possible within the given 30-minute time limit.

4. Results

For motivation, we found higher values in the gamification (experimental) group (EG) as opposed to the control group (CG). The total motivation score was 4.64 (SD=1.42) in the EG and 4.15 (SD = 1.37) in the CG. Across the four sub-dimensions we found similar differences (Table 1). The clearest differences were found for the dimensions social integration (Dim 1) and ability to make decisions (Dim 3).

More informative is the individual change in motivation (posttest value immediately after the mathematics session – pretest value). As illustrated in Figure 2, the individual total motivation score increased slightly in the EG (M = 0.56, SD = 0.95) while in the CG there was almost no change (M = 0.06, SD = 0.94). The effect was the same for female and male students. Equivalent results were found in the four sub-dimensions of motivation. An ANOVA yielded a significant main effect of the condition EG vs CG (F(1) = 4.85008); p = .032) and no main effect for gender (F(1) = 0.00535); p = .942) and no interaction (F(1) = 0.73397); p = .395). The effect size h^2 of the condition EG vs CG was 0.076.

Table 1: Average Motivation in experimental (EG) and control groups (CG)

	Dim 1		**Dim 2**		**Dim 3**		**Dim 4**	
	M	SD	M	SD	M	SD	M	SD
EG	4.69	1.70	4.34	1.76	5.06	1.69	4.52	1.42
CG	3.69	1.69	4.23	1.65	4.47	1.74	4.19	1.45
Diff EG - CG	1.00		0.12		0.59		0.33	

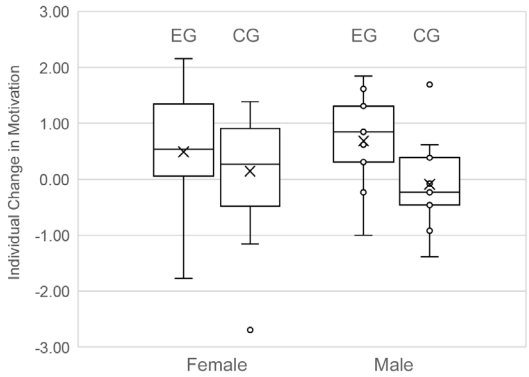

Figure 2: Individual change of motivation from pretest to gamified vs non-gamified sessions

In terms of performance, we found that the overall condition EG vs CG had an effect as well as the session date (gamification in the first session, no gamification in the second and vice versa). As shown in Figure 3a, the number of correctly solved tasks was clearly higher in the first session (T1: M = 32.58, SD = 19.89)) in comparison to the second session (T2: 48.87, SD = 29.56). Also, the condition (EG vs CG) had an effect; in the gamification condition the number of correctly solved tasks was lower (EG: M = 41.89, SD = 15.74) than in the paper-pencil condition (CG: 61.00, SD = 22.77). The sole consideration of the number of completed and correctly solved tasks is not a relevant factor for comparison between the conditions. The nature of the conditions renders such variables incomparable. The purpose of the gamification scenario is to facilitate communication and collaboration, which implies that the number of completed tasks may be lower. In terms of gamification, which fundamentally aims to enhance performance by motivating students, the key variable of interest is the loss of performance from one session to another. As depicted in Figure 3a, it is evident that in the gamification condition (EG), the decrease in performance (22%) is significantly lower than in the control group (CG) (69%). This

difference is quite remarkable. A repeated measures ANOVA yielded a non-significant main effect for condition (p =.157), however, a significant main effect of time (F(1) = 17.59, p = .001) and a significant interaction (F(1) = 13.64, p = .003). A comparison of the performance in relation to gender revealed a clear difference (Figure 3b), while in the CG no performance differences occurred, in the gamification condition (EG) males performed better than females. A Kruskal-Wallis test yielded a significant effect of gender (c^2 = 4.61, p = 0.032, e^2 = 0.153) and no significant differences by the condition (c^2 = 0.06, p = 0.804, e^2 = 0.002).

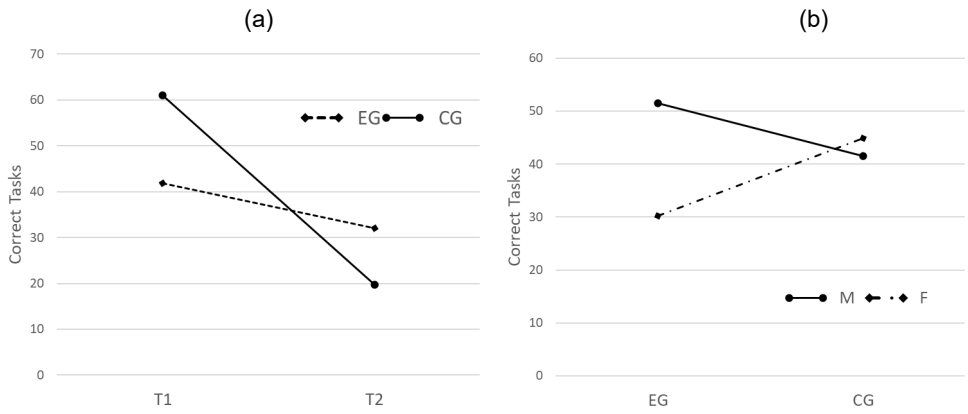

Figure 3: Performance (correctly solved tasks) in relation to session time (a) and gender (b)

The gamification scenario presented aims to promote collaboration within heterogeneous groups, with the expectation that stronger students would provide support to weaker students in order to maximize the overall performance of the group. Consequently, it was anticipated that stronger students would perform better in the absence of gamification (CG) and achieve lower performance in the gamification condition (EG). Conversely, it was expected that weaker students would benefit from the gamification condition (EG). When comparing the bottom and top 10% of students, we discovered indications supporting this effect. As illustrated in Figure 4, the stronger students (HP) performed clearly better in the CG (M = 82.00, SD = 13.92) than in the EG (M = 53.20, SD = 10.60). In turn, weaker students (LP) performed better in the EG (M = 11.60, SD = 3.91) than in the CG (M = 7.40, SD = 3.03).

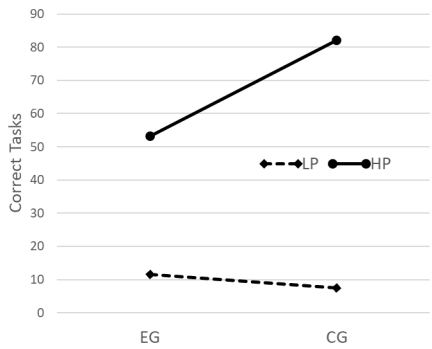

Figure 4: Performance (correctly solved tasks) in high (HP) and low performers (LP)

The analysis of the relationship between performance and motivation is summarized in Table 2. Overall, we found weak to moderate correlations between motivation and performance (defined as the number of correctly solved tasks). This holds for both, EG and CG. More interestingly, when considering the sequence of the respective session (EC – CG and CG – EG), we find stronger correlations in the second session, no matter if EG or CG. This is an indication that specifically in the second session the motivation plays a stronger role, presumably because motivation is substantially lower in the second session. In general, the dimensions ability to make decisions (Dim 3) as well as experience of capability (Dim 4) are stronger correlated with performance than the other two dimensions. The same effect was found for the individual change in motivation in relation to the pre-test scores (Table 2, Change). This remains difficult to interpret, it seems to be an indicator that the change – or an increase – in motivation is more relevant for the performance in a scenario without gamification support (CG).

Table 2: Correlation matrix of the dimensions of motivation and the total performance, time of the sessions (first EG followed by CG and vice versa), and the individual change in motivation

		Dim 1	Dim 2	Dim 3	Dim 4	Mot Tot
Total	EG	0.044	0.116	0.192	**0.382**	0.237
	CG	-0.229	-0.197	0.171	0.174	-0.013
EG - CG	EG	0.184	0.267	-0.169	**0.353**	0.235
	CG	-0.016	0.243	**0.423**	**0.469**	**0.323**
CG - EG	EG	0.135	0.276	**0.413**	**0.383**	**0.440**
	CG	0.074	-0.070	0.109	0.187	0.091
Change	EG	0.006	-0.063	0.082	0.054	0.051
	CG	-0.180	-0.299	**0.443**	**0.305**	0.218

5. Discussion

Research studies have revealed that collaborative educational environments, along with competitive educational environments, can contribute to the enhancement of various types of skills (Pareto et al., 2012). Furthermore, there is evidence suggesting that competitive reinforcement may have a more significant impact on the gaming experience of players compared to collaborative approaches involving positive and negative reinforcement (Sekhavat, 2020). Nevertheless, the effects of combining competition and collaboration, as well as how to effectively utilize the benefits of competitive reinforcement in collaborative-competitive serious games (CCSG), remain uncertain (Buchinger & da Silva Hounsell, 2018). For the relatively new genre of CCSG, it is crucial to systematically identify and compile design features for such games. The present study contributes to the comprehension of the effects of collaborative-competitive design features and mechanics.

In this paper, we presented a gamification scenario for an entire school lesson, emphasizing that competition is a strong motivating factor for students. However, we also discussed the potential downsides of gamification mechanics, particularly in relation to competition. For certain students, such as low performers and socially less integrated students, competition can have a negative emotional impact that may lead to a decline in performance. To mitigate these effects or at least reduce them, we proposed shifting the competition to heterogeneous groups consisting of both high and low performers as well as socially high and low integrated students. By doing so, we aimed to minimize individual students' exposure and promote communication and collaboration within the groups.

We implemented the gamification scenario in the context of a mathematics lesson and compared motivation and performance with a conventional, non-gamified scenario. Overall, we observed significant positive effects of gamification. Motivation in the gamification scenario (EG) increased compared to a baseline score, in contrast to the non-gamification scenario. This effect was observed for both female and male students, with the gamification condition (EG) showing higher motivation overall. The most notable difference in motivation was observed in the dimension of social integration (Dim 1), where average motivation in the gamification condition was one point higher on the 7-point Likert scale compared to the non-gamification condition (cf. Table 1).

When examining the performance difference between the gamification and non-gamification conditions, we did not specifically measure learning performance, but rather the extent to which students could demonstrate their competencies within the given session duration of 30 minutes. It is reasonable to assume that there was no increase in mathematics competencies for stronger students. However, weaker students may have benefited from the exchange with stronger students and potentially gained competencies. Identifying such effects will be a goal for future studies.

Task performance, as measured in this study, clearly demonstrated advantages for the gamification condition. It is important to highlight that the number of completed or correctly solved tasks alone is not a comprehensive performance indicator. It is expected that such figures would be higher in the non-gamification condition (CG), where all students can solely focus on completing mathematics tasks throughout the entire session. In contrast, in the gamification condition (EG), students dedicated time to communication and collaboration. The true desirable goal of gamification lies in (i) facilitating mutual benefits and social integration, (ii) increasing participation, and (iii) enabling students to showcase their full potential. Similar effects have been investigated in the context of sports education (Perlman, 2021; Ullrich-French, McDonough, & Smith, 2013), with studies

demonstrating the benefits of group activities and even positive relationships with academic performance (Trudeau & Shephard, 2008).

In our study, we found that overall performance was lower in the gamification condition, but the performance decline in the second session was significantly lower with gamification. The gamification condition outperformed the non-gamification condition in the second session, indicating a remarkable and promising interaction effect (cf. Figure 3a). It is worth noting that females performed significantly less in the gamification condition, while no differences were found in the non-gamification conditions (Figure 3b). A possible explanation could be that females invest more time in supporting others and may have a stronger aversion to competitive elements compared to males. This finding aligns with the results of a large sample study conducted by Hartmann and Klimmt (2006).

One of the most positive effects observed was that the performance gap between stronger and weaker students was smaller in the gamification condition (Figure 4). This finding is further supported by the teacher's records during the gamification sessions. In summary, the teachers documented 31 communicative events in the gamification condition compared to 8 in the non-gamification sessions, as well as 27 collaborative events in the gamification condition compared to 8 in the non-gamification condition. Typical recorded events included instances where the strongest student assisted the weakest, continuous communication among students, and instances where a student who completed their tasks early helped others. Only in one group, which conducted the non-gamification session in the second time slot, did the students start communicating and comparing results.

Whether higher motivation and the associated increased effort exhibited by students justify the application of gamification remains a topic of ongoing debate. In conclusion, it is important to maintain realistic expectations regarding the potential benefits of gamification. Our study demonstrated that gamification can elicit various desirable effects in students. At the same time, it is crucial to raise awareness among developers and users about potential unintended and detrimental effects, such as embarrassing low performers. Future research must increasingly consider these effects and explore their long-term impacts.

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Evaluating the Impact of Serious Games on Study Skills and Habits

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Abstract: Learning is a constructive process that requires dedication and motivation. Learning games can be used to engage learners, by providing opportunities to apply knowledge in a safe and fun environment. We created a peer-quizzing game that allows students to quiz each other on the course material and to playfully engage in good study habits. We set out to explore if learners with better learning skills and habits would be more engaged in the game in the context of a first-year computer science university class. We used the "Study Skills and Habits Questionnaire" to study the relationship between study skills and habits (especially time management, concentration, goal setting, and comprehension) and engagement in a competitive version of a peer-quizzing game including a leaderboard. We collected and analysed gameplay data of the students (n=34), such as creating quiz questions and solving the questions created by their peers. The results of the data analysis showed a moderate positive correlation between study skills and habits (time management, concentration, goal setting, and comprehension) and the number of questions answered and a moderate negative correlation with the number of questions created in the game. However, the regression model was not statistically significant in explaining the variation in the dependent variable (questions created). Among the individual predictor variables, only goal setting had a statistically significant positive effect on the number of questions created. Other variables, such as time management, concentration, and comprehension, did not show significant effects on the number of questions created by students.

Keywords: Serious games, Peer-quizzing, Engagement

1. Introduction

The recent popularity of game-based learning and serious games has influenced researchers to experiment with various approaches. Researchers using game-based learning tools and serious games have mostly reported having a positive impact from their implementations (Anastasiadis et al., 2018; Arif et al., 2022; Landers et al., 2017; Lin et al., 2017). Learners enjoy game-based learning and serious games because of the extra layer of entertainment and excitement added by interacting competitively with their peers in an environment constrained by the game mechanics and dynamics related to a learning task. Some common game elements are points, badges, and leaderboards. Using these game elements, the hardship of the main task becomes less noticeable because of the rewards and satisfaction. Researchers have explored various game elements, and the design process of game-based solutions and serious games welcomes exploration and creativity (Arnab et al., 2015; Chou, 2015; Nah et al., 2013; Wang et al., 2016).

Learning is a natural process that takes place both inside and outside the classroom. We learn various things both voluntarily and involuntarily. Sometimes we learn things by experience, and sometimes by hearing others' experiences. Either way, learning is fun as long as the learners are motivated (Bergin & Reilly, 2005). Game-based learning is an innovative approach to teaching that uses games to deliver educational content. The method has been shown to increase student engagement and motivation (Sailer et al., 2017) and to improve learning outcomes. Serious games, on the other hand, are games designed with a primary purpose other than learner motivation. Serious games are created with the intention of passing knowledge, developing specific skills by practicing them in a simulated environment, or changing behaviours in a targeted audience.

Both game-based learning systems and serious games often include leaderboards, which are used to track and display players' performance. Leaderboards can be a powerful motivator for students, as they provide a way to compare their performance with that of their peers (Huang & Hew, 2015). However, leaderboards are not equally motivating for learners. While they may be very motivating for competitive students, they may be demotivating for others (Toda et al., 2018; Wells & Skowronski, 2012). It is likely that personality type, the student's mindset, self-efficacy, and study skills and habits play a role in the motivational effect of games on students.

Survey tools are widely used to identify individual features of learners. The "Study Skills and Habits Questionnaire" (SSHQ) is a standardized assessment tool to measure an individual's study habits and skills (Nourian et al., 2008). It is designed to assess a range of study-related behaviours and attitudes important for academic success, such as time management, note-taking, concentration, and motivation (Nourian et al., 2006). The questionnaire typically consists of a series of statements or questions that the individual answers using a

Likert scale, which measures the degree to which they agree or disagree with each statement. The responses are then scored and analysed to provide insights into the individual's study habits and skills. Educators and academic researchers often use the Study Skills and Habits Questionnaire to evaluate the effectiveness of different teaching methods, study programs, and interventions to improve student study skills and habits.

We aim to explore if study skills and habits play any role or show any associations with gameplay behaviours in an educational game. We designed a study in which we measured the study skills and habits of students before playing a competitive learning game during one semester of a first-year university programming course. We focus on a competitive game, because competition is an important factor that contributes to enjoyment and facilitate social activities (Vorderer et al., 2003). Using the SSHQ, we analyzed the relationship between student study skills and habits and their gameplay behaviours. The findings will allow game designers to tailor educational games to individual students.

2. Related Literature

In recent years, research into learning games has grown significantly. In addition to enhancing engagement, participation, and academic success, learning games as a pedagogical tool can also be used in creating and developing other skills in, such as research skills (Bellotti et al., 2013), leadership skills (Sousa & Rocha, 2019), communication skills, creativity, and adaptability (Barr, 2018). Prior studies, however, have demonstrated that student individual characteristics need to be considered. Otherwise, students may initially show interest and engagement in the learning process but as time goes on, their interest wanes and their performance declines (Hwang et al., 2012). For this reason, researchers are exploring the potential for profiling learners (Omarali, 2016; Tzouveli et al., 2008). For example, Hwang et al. (2012) propose a personalized learning games approach based on learning styles' sequential/global dimension. An experiment using a role-playing game in an elementary school science course was conducted to evaluate the method. Results indicate that personalized educational computer game enhances learning motivation and improves student achievements. Troussas et al. (2020) proposed a mobile learning tool "Quiz Time!" evaluating and increasing students' understanding of the programming language C#. The tool offers a personalized group play suggestion for collaboration using a vectorial-based recommendation module and tailored support based on the learner's profile using a dynamic fuzzy logic-based advice generator. Bang et al. (2023) utilizes My Math Academy, an adaptive Personalized Mastery Learning System to determine the effect of personalization on student learning gains. The system provides personalized math materials and adaptive embedded evaluations based on students' abilities. The researchers discovered that My Math Academy users significantly improved their math skills compared to non-users.

A study conducted by Denden et al. (2018) introduces a novel framework for modelling learners' personalities within a learning environment based on their gaming behaviours instead of just traditional surveys. The framework comprises a Computer Architecture Game (CAG) and a Learning Analytics (LA) system. The experiment involved 34 undergraduate learners and 11 teachers from a Tunisian University. While playing the CAG, the participants' gaming behaviour traces were collected, and their personalities were assessed using the Big Five Inventory (BFI) questionnaire. The results showed that the framework accurately modelled extraversion and openness personality dimensions and demonstrated moderate to good agreement compared to the BFI. The study suggested that this framework could advance learning games and educational psychology research by providing alternative methods for modelling learners' personalities without relying solely on questionnaires. However, the study had limitations, such as focusing only on the extraversion and openness dimensions, a small number of participants, and using only one algorithm (Naïve Bayes classifier) in the LA system.

Another study by Mekler et al. (2013) discussed the effects of implementing game elements, such as points, levels, and leaderboards, on user performance, intrinsic motivation, perceived autonomy and competence. In the study, participants were randomly assigned to one of four experimental conditions and asked to complete an image annotation task. The results suggested that implementing points, levels, and leaderboards may be an effective way to drive user behaviour in the short term and enhance performance in the task. However, the presence of these game elements did not increase intrinsic motivation. Therefore, designers of gamified services should be aware of potential social or contextual factors that may affect intrinsic motivation and not rely solely on game elements to sustain long-term user engagement.

Reyes et al. (2023) investigated a model predicting academic accomplishment. The findings demonstrated that learning strategies, study habits, and attitudes mediate the relationship between students' academic success and individual characteristics such as age, gender, and cognitive or behavioural involvement. Numan & Hasan (2017) conducted a study to determine the impact of study practices on undergrad students' test anxiety and

academic performance. They found that students who practise efficient study techniques score higher on academic tests and have lower levels of test anxiety. Furthermore, the research showed that girls outperform boys in the classroom and had better study habits. Additionally, the authors conducted a correlation analysis, revealing a strong positive association between study habits and academic success and a negative relationship between test anxiety, academic success, and study habits.

3. Experiment Design

This section presents our research methodology, how we recruited the participants, designed our experiment, and collected the data.

3.1 Recruitment of Participants

Our study was approved by the ethics board at the university with BEH ID-101. We recruited students from a first-year programming language course at our university. We used a pre-study survey to collect the students' demographic information, which also contained the "Study Skills and Habits Questionnaire" (SSHQ) questionnaire[1]. We used the SSHQ version from Queen's University's Learning Strategies and the Writing Centre[2]. The pre-study survey started with a consent form for participation. Participation was voluntary, and students who participated in our study received up to five percent of the final grade as participation marks in the class, depending on how actively they participated in the game. Students who opted out of the study had five percent weight added to their final exam.

Initially, 165 students signed up for the study. We randomly assigned the students into one of two groups, playing different versions of the game, one with leaderboards, and one without (just points). However, only 79 students played the game regularly. In this paper, discuss the results from the group with the leaderboard (n=34).

3.2 Peer-Quizzing Game

The participating students were assigned a pseudonym to play the quizzing game. The game is themed as a tower defence game where students create quiz questions based on the material from their course. They can create three types of quiz questions in the game: multiple-choice question (MCQ), true/false, and short answer. The students can create quiz questions, answer the questions created by their peers and view the solved questions. They receive points for creating and answering quiz questions correctly. In the game, asking a quiz question is synonymous with creating a tower, and answering a question is synonymous with attacking a tower. The game interface included two leaderboards, showing respectively the students who created and those who attacked the most towers. More information about the design of the game can be found in (Kiron et al., 2019).

3.3 Data Collection

Apart from the answers to the pre-and post-study survey questions, we collected each student's gameplay data. The gameplay data consists of the number of questions created and answered. In addition, we also collected a detailed log of all the events in the game, such as, the questions they created, answered, viewed, when they signed in and out with timestamps.

4. Data Analysis and Results

To study the relationship between students' study skills and habits and their engagement in the game multiple regression analysis was performed to examine the relationship between a dependent variable and multiple independent variables. In our case, we did two multiple regressions examining respectively the relationship between the number of questions answered (dependent variable 1) and the number questions created (dependent variable 2) and the students' time management, concentration, goal setting, and comprehension skills (independent variables). The goal is to identify the relationship between the variables and determine how much of the variance in the dependent variable can be explained by the independent variables. We also calculated the correlation coefficient between the four SSHQ items for study skills and habits and the numbers of questions created and answered. For analysis, we used the data analysis toolkit in Microsoft Excel. The results of the regression statistics, ANOVA, and regression analysis are presented in tables 1 to 3 below.

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[1] https://www.scribd.com/document/535856383/Study-Skills-Habits-Questionnaire-2019 (At the time writing this manuscript, the original link was not operational. Therefore, we cited an alternative link containing the version we used for our study.)

[2] https://sass.queensu.ca/

4.1 Number of Questions Answered

As shown in Table 1, the multiple correlation coefficient (R) is 0.739. This indicates a moderate-to-strong positive correlation between the dependent (# of questions answered) and independent variables. The coefficient of determination (R squared) is 0.546. This means that 54.61% of the variation in the dependent variable is explained by the independent variables included in the model. The adjusted R squared is 0.212. This means that the independent variables in the model explain only 21.16% of the variation in the dependent variable after adjusting for the number of predictors in the model. The standard error of the estimate is 1.098. This represents the average distance the data points fall from the regression line.

Table 1: Regression Statistics for variables under the number questions answered.

Multiple R	0.738954
R Square	0.546053
Adjusted R Square	0.211566
Standard Error	1.098107
Observations	34

The ANOVA results in Table 2 show that the regression model is not significant at the 0.05 level of significance (p-value of 0.158). This means that the independent variables in the model do not significantly explain the variation in the dependent variable.

Table 2: Results from the ANOVA for variables under questions answered.

	df	SS	MS	F	Significance F
Regression	14	27.55963535	1.968545382	1.632510112	0.158264087
Residual	19	22.91095288	1.205839625		
Total	33	50.47058824			

The regression analysis in Table 3 provides the estimated coefficients for each independent variable. The intercept is 6.565. In a regression model, the intercept refers to the predicted value of the dependent variable when all independent variables are set at zero. It represents the average response that would be observed if all other factors were held constant and only one factor was varied. None of the independent variables are significant at the 0.05 level. Academic stress, with a p-value of 0.0731, though it is not less than 0.05, has a relatively lower p-value than the other variables, suggesting it could potentially be a significant predictor. Academic stress and attitude were not one of the items we were looking into for our present study, but we still included the items in table 3. A negative coefficient for an independent variable means a negative relationship between that variable and the dependent variable. For example, a one-unit increase in attitude is associated with a 1.257 decrease in the dependent variable.

Table 3: Results of the regression analysis for variables under questions answered.

	Coefficients	Standard Error	t Stat	P-value
Intercept	6.564505	2.917575233	2.249986524	0.036494338
Time management	-0.24144	0.586526951	-0.411636983	0.685211975
Concentration	-0.04986	0.363299588	-0.137239796	0.892285141
Goal setting	0.795159	0.776733698	1.023721844	0.318824939
Comprehension	0.234686	0.497424447	0.471802295	0.642440914
Attitude	-1.25702	0.70686428	-1.778308679	0.091360561
Academic stress	0.836127	0.440691843	1.897304381	0.073091995

4.2 Number of Questions Created

In Table 4 we can see that the multiple correlation coefficient between the second dependent variable, (# questions created) and the independent variables is close to 0.703. It indicates a moderate positive correlation.

The coefficient of determination is 0.494. It means that the predictors in the model explain approximately 49.4% of the variability in the questions created. The adjusted R-squared value is 0.121. It considers the number of predictors and the sample size to provide a more conservative estimate of the model's explanatory power. In this case, the adjusted R-squared is lower than the R-squared, suggesting that some predictors may not significantly contribute to the model's predictive ability. The standard error is 1.157. It represents the average deviation of the observed values from the regression line. Lower values indicate a better fit of the model to the data.

Table 4: Regression Statistics for variables under questions created.

Multiple R	0.702854712
R Square	0.494004747
Adjusted R Square	0.121166139
Standard Error	1.156647159
Observations	34

In Table 5, the regression analysis shows that the model with the predictors is not statistically significant (p = 0.279, and the F- statistic is higher than the critical value). However, the F-statistic of 1.325 suggests that the overall model's fit is not strong. The residual sum of squares (SS) is 25.419, indicating the unexplained variability in the data after accounting for the predictors. The total sum of squares (SS) is 50.2353, representing the total variability in the questions created.

Table 5: Results from the ANOVA for variables under questions created.

	df	SS	MS	F	Significance F
Regression	14	24.81647375	1.772605268	1.324982812	0.279349298
Residual	19	25.41882037	1.337832651		
Total	33	50.23529412			

Table 6 shows that the intercept term is 1.595 with a standard error of 3.073. The t-value of 0.519 suggests that the intercept is not statistically significant (p = 0.609). The coefficient for goal setting is 2.153. It suggests that for each unit increase in goal setting, there is an expected increase of 2.153 in questions created. The t-value of 2.631 and the p-value of 0.017 indicate that this effect is statistically significant. The rest of the independent variables do not yield statistically significant effects.

Table 6: Results of the regression analysis for variables under questions created.

	Coefficients	Standard Error	t Stat	P-value
Intercept	1.594860372	3.07311055	0.518972665	0.609772197
Time management	-0.844538358	0.617794578	-1.367021316	0.187576218
Concentration	0.345650813	0.382667012	0.903267859	0.377693646
Goal setting	2.152645786	0.818141206	2.631142118	0.016452696
Comprehension	0.065774261	0.523942039	0.125537284	0.901417033

In summary, the regression analysis indicates that the overall model is not strongly predictive of questions created, as evidenced by the low R-squared value and the non-significant F-statistic. Among the individual predictor variables, only the goal setting variable appears to have a statistically significant effect (p = 0.0165) on the outcome variable. This suggests that goal setting has a significant positive effect on the number of questions created. This finding implies that participants who have better goal-setting skills tend to create more questions.

In Table 6, the results presented a regression analysis, examining the relationship between variables under questions created. Each variable's coefficient, standard error, t-statistic, and p-value are provided. The p-value indicates the statistical significance of each variable in the regression model. A lower p-value suggests a stronger statistical significance. On the other hand, Table 7 displays the correlation coefficients between four items of the SSHQ and questions created, as well as questions answered. Correlation coefficients measure the strength and direction of the linear relationship between two variables.

From Table 7 we can see that there is a weak negative correlation between time management and questions created. This suggests that students with poor time management skills may have a slightly higher tendency to create more questions. Furthermore, a weak positive correlation exists between time management and questions answered. This implies that students with better time management skills may tend to attack questions slightly more.

Table 7: Correlation coefficient of four SSHQ items against questions created and answered

	Created	**Answered**
Time management	-0.05552	0.082009
Concentration	0.192323	0.163968
Goal setting	-0.24212	0.224018
Comprehension	-0.09412	-0.01572

A moderate positive correlation exists between concentration and both questions created and answered. This may imply that students with higher concentration levels are more likely to create and attack questions. When it comes to goal setting, there is a moderate negative correlation between goal setting and questions created. This may suggest that students with higher levels of goal setting may have a lower tendency to create questions. However, there is a moderate positive correlation between goal setting and questions answered. This may imply that students with better goal-setting skills may have a higher tendency to attack questions.

While comparing the p-values for the "Goal setting" variable in both tables, in Table 6, the p-value for "Goal setting" is 0.0164, which is below the conventional threshold of 0.05. This suggests a statistically significant relationship between "Goal setting" and questions created in the regression analysis. In Table 7, the correlation coefficients shown for "Goal setting" and questions created is -0.24212. However, correlation coefficients do not directly provide p-values. The p-value in Table 6 represents the significance of the "Goal setting" variable in the context of the regression model. In contrast, the correlation coefficient in Table 7 only indicates the strength and direction of the linear relationship between "Goal setting" and questions created.

The p-value in Table 6 demonstrates the statistical significance of the "Goal setting" variable within the regression analysis. In contrast, the correlation coefficient in Table 7 illustrates the strength and direction of the linear relationship between "Goal setting" and questions created. The different p-values between the two tables may arise from the nature of the statistical analyses and the specific data used in each calculation.

Regarding comprehension, there is a weak negative correlation between comprehension and questions created. This may suggest that students with lower levels of comprehension may be slightly more reluctant to create questions. Additionally, there is a very weak negative correlation between comprehension and questions answered.

5. Discussion and Limitations of the Study

Overall, there was only one significant relationship discovered in the analysis, between goal-setting and the number of questions created. One thing to note is that the Adjusted R-squared value in Tables 1 and 4 is substantially lower than the R-squared value, indicating that some of the variables in the model may not be contributing much. This suggests that the model may benefit from removing some of the less important variables and revising the selected variables may change the results. Additionally, some of the p-values for the coefficients are quite high, indicating that there is not enough evidence to reject the null hypothesis that the coefficient is zero. This suggests that these variables may not significantly impact the dependent variable. These results may be due to the fact that the participants group in this study was small. The general recommendation for linear regression models (including multiple regression) is to have 10-15 observations for each term. In our case this means 40-60 participants. Possibly more significant relationships could be found in a larger study

Overall, many versions of the Study Skills and Habits Questionnaire have been developed[3, 4] and validated by researchers in the field of educational psychology. These questionnaires typically undergo rigorous testing and validation to ensure that they measure the intended variables and produce consistent results over time. However, it's important to note that no assessment tool is 100% reliable, and factors can affect the validity of the results, such as individual differences in response styles or the influence of external factors like stress or anxiety. For our present study, we relied on the students' survey responses and the data we collected from the game. Therefore, it's essential to use the Study Skills and Habits Questionnaire in combination with other sources of information, such as interviews or direct observations, to obtain a complete picture of an individual's study skills and habits.

It is also important to remember that this is study is carried out in specific context (specific game and course) and we can't say for sure if these results apply to everyone. Many other factors, like coursework load, students' social life, and individual differences, can influence their behaviour in the game. Therefore, we need to study more to understand what makes some students more engaged in competitive learning games.

6. Conclusion

Serious games have become prominent in educational research that can aid in various learning outcomes. An enjoyable serious game influences students' motivation and interest in the game objectives or learning tasks. Learning abilities and habits are two additional factors that can also affect students' motivation to engage in learning tasks, which should be considered in the research on student engagement and academic success. To aid in this research, we investigated the effect of learners' study skills and habits on the student engagement in a peer-quizzing serious game.

The paper discusses using a serious game to engage students and improve their study skills and habits. We developed a learning game that allowed students to quiz each other on course material in a fun and interactive way. The study explored whether students with better learning skills and habits would be more engaged in the game. Therefore, we used the "Study Skills and Habits Questionnaire" (SSHQ) to assess various factors related to academic success, such as time management, concentration, goal setting, and comprehension.

We recruited thirty-four students to participate in the study. Gameplay data, including quiz creation and solving, were collected, and analyzed. We performed regression analyses and calculated correlation coefficients to examine the relationship between study skills and habits and engagement in the game.

The results showed a moderate positive correlation between study skills and habits (time management, concentration, goal setting, and comprehension) and the number of questions answered and a moderate negative correlation for questions created in the game. However, the regression model as a whole was not statistically significant in explaining the variation in the dependent variable (questions created). Among the individual predictor variables, only goal setting had a statistically significant positive effect on the number of questions created. Other variables, such as time management, concentration, and comprehension, did not show significant effects on the number of questions created by students.

The findings suggest that students with goal setting skills tend to engage in the game and create more questions. However, it is essential to note that the study has limitations: the sample size was small and the SSHQ survey covers only a limited set of personal variables. Further research is needed to understand the broader factors that influence engagement in serious games. Factors like course schedule, and individual differences, e.g., personality traits, can also impact students' engagement. While a valuable tool, the Study Skills and Habits Questionnaire should be used in conjunction with other sources of information to gain a comprehensive understanding of students' study skills and habits.

In conclusion, serious games can effectively engage students and improve their study skills and habits. In addition, the study found a positive correlation between goal-setting and engagement in the game, indicating that students with better goal-setting skills were more likely to participate actively. However, more research is needed to explore the broader factors that contribute to academic success and validate this study's findings.

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[3] https://smgserv1.bu.edu/studyskills/

[4] https://www.uhcl.edu/counseling-services/resources/documents/handouts/study-skills-assessment-questionnaire.pdf

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First Steps to Improve Cybersecurity Behaviour: A Virtual Reality Experience

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Abstract: Internet is completely integrated and absorbed in our life. Facilitating transfer of files across the world or wiring money from the couch, we could not imagine a world without it anymore. With these benefits, as with any new technology, there is also the introduction of risks and threats, for internet primarily in the form of cybercrime and online fraud. To reduce victimisation of this cybercrime, interventions are used to teach people to not perform risky behaviour. To overcome criticisms of current training materials, such as being tedious and boring, we created an Immersive Virtual Reality experience. By using a 4-step design process (i.e. ideation, specification, realisation, and evaluation), we designed a playful VR environment with simplistic non player characters to train the user to perform basic cybersecurity tasks in the right way. In the simulation, the participants are exposed to the challenge of creating a new password and a potential ransomware attack using USB storage device. The program allows for monitoring the user's cybersecurity knowledge and behaviour and provides feedback. An evaluation of the VR environment among 16 respondents using a pretest-posttest evaluation with the Human Aspect Information Security Questionnaire (HAIS-Q) showed a statistically significant increase in scores after exposure to the VR environment. The system showed an above average SUS score. These initial findings indicate that a VR environment can be an alternative to consider for future development of cybersecurity interventions. Future research could expand our social VR environment with additional cybersecurity challenges, real-time actors, and running simulations among a broader audience to also investigate the retention of knowledge and skills.

Keywords: Cybersecurity, Design, Immersive virtual reality, Intervention, Prototyping, USB drop

1. Introduction

The internet has become an indispensable part of our lives, offering the ability to connect with people from all corners of the globe, and conduct financial transactions from the comfort of our couches. However, it also comes with risks in the form of cybercrime and online fraud. From phone calls from fake bank representatives to scam text messages, it is important to remain vigilant to protect ourselves online.

To reduce vulnerability to cyber threats, typically two types of defences are deployed: technical and non-technical (Pollini et al, 2021). Technical defences involve the use of automated techniques, such as machine learning algorithms, to identify and prevent cyber threats. For example, automated detection of malicious software, unauthorized access attempts, and other suspicious activities on computer networks (Marchal et al., 2017). Although techniques can detect advanced attacks in certain conditions, they are limited by their reliance on past data. Therefore, additional measures may be necessary to detect potential attacks.

Non-technical defences, involve training users to become proficient in recognizing and responding to cyber threats. This can include educating users on how to secure their devices and networks, recognizing and reporting phishing attempts, and staying up to date on the latest security risks and best practices. Typical ways of delivering such user training are in text-like format, which users must read, classroom lecturing, or e-learning (Dahabiyeh, 2021). While these methods might be cost efficient, the user experience is sometimes tedious or boring (Aldawood & Skinner, 2019).

To offer more engaging experiences, there are serious games that teach about various forms of cyberthreats, for instance, around document inspection of phishing emails akin to the game *'Papers Please'* (Wen et al. 2019). An alternative approach that could be even more engaging and can be at least as effective is the implementation of a cyber security training in an Immersive Virtual Reality (IVR) (Veneruso et al, 2020). The goal of our current work is to explore the potential use of IVR for training to reduce vulnerability against cyber threats. Specifically, our contribution lays in our investigation of opportunities to train for both online (e.g. password choice) as well as real-world behaviours (e.g. the use of a USB thumb stick, physical access, and/or social interactions).

In this paper we will first discuss related work. We then point out the chosen design process for creative technology which fits novel integrations of existing technologies (Mader & Eggink, 2014, Mader & Dertien, 2014) it adds intermediate structuring points to methods such as the spiral model for reflective transformative design (Hummels & Frens, 2009). In our process we highlight expert interviews as an important grounding step for designing our intervention. Afterwards, we show the resulting design including the underlying design rational. Following this, we present our evaluation, first the method, and second the results of how evaluated the environment on effectiveness of training and usability using a convenience sample (N=16). We finish the paper with a brief discussion including possible future steps.

2. Related Work

A thorough investigation about games for cybersecurity is outside the scope of this paper, so we use examples only to provide an overview of general directions. In the field of game-based learning of cybersecure behaviour there are mobile app games such as *CyberAware* (Giannakas et al, 2015), online games such as *What.Hack* (Wen et al. 20019), PC games such *CyberCIEGE* which combined this with an online scenario database (Irvine et al 2005), and our direction of immersive VR intervention for which we only encountered *CyberVR* (Veneruso et al 2020). Besides the form an important distinction can be seen in the type of training that is offered.

Samy et al. (2010) took a broad approach to identifying threats to cybersecurity, identifying 22 elements in a healthcare setting. Huang et al (2010) adopted a similar broad strategy and established 12 categories of cybersecurity threats. Badie and Lashkari (2012) defined nine less generalised factors. The categories included technical hardware/software failures, forces of nature, or deliberate acts of espionage and trespass. In these overviews several descriptions are used for the human error, which is the focus of our work: acts of human error or failure, staff shortage, and operational issues (Samy et al, 2010), “acts of human error or failure” (Huang et al, 2010), and error and omission, phishing, and social engineering (Badie and Lashkari, 2012).

In various estimates human error is recognised as the biggest source of security breaches (Nobles,2018). Huang et al. (2010) also recognize this importance, delineating the human factor as the weakest point in information security. In the past this human aspect has regularly been disregarded (Nobles,2018, Pollini et al, 2021). Metalidou et al. (2014) even assert that technology is regularly recognized as the only fix of these problems.

Even the field of human error within security breaches is very broad and to build an intervention within the scope of our project we need a better view on aspects of human error. When looking at literature there is consensus on at least two human factors, lack of knowledge (Desolda et al, 2022, Huang et al 2010, Pollini et al 2021, Metalidou et al, 2014, Zimmerman & Renaud, 2019) and a related lack of awareness (Desolda et al, 2022)) Zimmerman and Renaud (2019) and Pollini et al (2021) both expand this with lack of skills, and the latter also add violations, the lack of adherence to rules, and malicious violations. Similarly, Zimmerman and Renaud (2019) include the possibility of malicious users, this vulnerability encompasses those who make the “mistakes” without the intent of doing the right thing. Metalidou et al. (2014) appoint risky belief, risky behaviour, and inadequate technology use as additional vulnerable human factors. Desolda et al. (2022) describe the vulnerability of norms and complacency. Unsafe norms are practices users become accustomed to over time (e.g., not locking the office/computer when leaving the workplace). Complacency is users' self-overestimation of cybersecurity skills, which can in term be related to a lack of knowledge and awareness. Another human vulnerability is a lack of policies and compliance, which are predetermined written guidelines which an employee should adhere to (Zimmerman & Renaud, 2019).

Gillam and Foster (2020) use another approach towards defining human error, culminating in the use of Human Aspect Information Security Questionnaire (HAIS-Q) by Parsons et al (2017), to identify vulnerable areas rather than underlying reasons. Using the HAIS-Q is a holistic method of measuring human factors in cybersecurity (Parsons et al, 2017). It differentiates between seven topics: 1) password management, 2) e-mail use, 3) internet use, 4) social media use, 5) mobile devices, 6) information handling and 7) incident reporting. These topics are more specialised and application oriented; moreover, they constitute known security risks related to the human factor. Consequently, these topics should be part of a cyber security training.

3. Design Process Based on Interviews

We follow a design process fitting for creative technology (Mader & Dertien, 2014) consisting of 4 steps: ideation, specification, realisation, and evaluation (Mader & Eggink, 2014). This approach employs a balance between divergent and convergent steps, and spiral models such as the Eindhoven Reflective Transformative Design Process (Hummels & Frens, 2009) while adding more structured intermediate steps. An important step in our

ideation and subsequent specification was a semi-structured interview with two experts handling cybersecurity at our university, for which we obtained a positive advice from our Ethics Committee Computer & Information Science under RP 2022-27.

Although, the related work already provided a picture on relevant topics, with a semi-structured six question interview we wanted to get a better grip on the most dangerous and/or often occurring errors. We started with an introduction of the interviewer and the aim of the project. The first three questions were themed 'current ways of monitoring, testing, and educating cybersecurity'. Sample questions include: "*Which audience performs the worst in your cybersecurity testing and who performs the best? Do you have any idea why this is the case?*" and "*How do you test employees on their cybersecurity knowledge? Has it proven to be effective?*". The next three questions where themed 'mistakes and important topics'. Sample questions include: "*What are the most often made mistakes in cybersecurity that you encounter?*" and "*What are the topics that in your opinion should most definitely be treated in a cyber/ information security awareness training?*".

Regarding the question about which mistakes are made most often, sample responses included: "*Phishing and maltreatment of privacy sensitive cases. The most dangerous ones are those that include getting a virus on the computer. This can be through opening an email attachment or plugging a found USB with software in the computer.*" (interviewee 1) and "*Most dangerous mistakes are those where human weakness is exploited.*" (interviewee 2).

The interviewees discussed recent cybersecurity assessments and training programs at our university. In a baseline program in 2021 47% of employees and students participated. This program assessed awareness on 7 different topics. The results can be grouped into three classes based on average performance. Participants performed worst on protecting mobile devices and information. The second worst topic was related to phishing, social media and secure data protection and disposal. The third topic regarded protection against scams, physical risks, and safe use of the internet.

According to the first interviewee the most common human mistakes in cybersecurity are related to phishing and maltreatment of privacy sensitive cases. The most dangerous ones are those that include getting a virus on the computer. This can be through opening an email attachment or plugging a found USB with software in the computer. The second interviewee generalises this answer by saying that the most dangerous mistakes are those in which human weakness is exploited. Given examples included hack attempts, phishing and social engineering. It also includes the use of personal information from social media (e.g., to answer password reminders or find usernames). Hence, according to this, the topics that should be treated are password management: strong passwords, no reuse, and multi-factor authentication. Secondly, a topic to be treated in the training is the importance of thinking before handling, taking a break when things do not seem right. Somewhat related to the latter, the training should also help to recognize social engineering techniques.

4. VRCyberEducation

Based on the interviews combined with the related work, we highlight two very concrete elements to train in the domain of human error in cybersecurity, spanning the physical and digital realm: *password management* and *removable media use*. Using strong passwords is key for cybersecurity; in 2020 approximately 20% of initial attack vectors against companies are compromised credentials (Juozapavičius, 2022). Removable media and USB storage devices should be handled with care and can cause malware or ransomware attacks. Exemplary is the infected USB storage device that was used to sabotage an Iranian nuclear power plant (Chen, 2011).

The result of our iterative design process and especially the specification and devised steps is the immersive VR world *VRCyberEducation* accessible within a Social VR platform. We designed VRCyberEducation to address poor information security awareness among staff members of an organization. We chose for Social VR (networked VR environments where users are represented with virtual avatars) to provide a variety of possible follow-up studies (e.g., have multiplayer scenarios).

To be able to program interactions within a Social VR world and building on personal experiences regarding ease of use with available platforms, we chose for the freely accessible NeosVR. This platform had several benefits. NeosVR already includes user input from handheld controllers and/or VR headset for navigation and object interaction (including grabbing) within the virtual environment. It supports most types of VR hardware (i.e., relying on SteamVR) including the Oculus Quest 2 we had available. It is capable of integrating physical and cyber aspects of cybersecurity within the program through programming a variety of interaction-responses. The program also eased distribution, in NeosVR users can open and share worlds between accounts, whereas Unity

does not take care of the distribution. Finally, fitting this context we could quickly emulate a realistic, lifelike virtual environment through importing various freely accessible assets.

These assets included an office building we constructed through combining a blueprint and 3D models from Turbosquid and Sketchfab. We added doors to let users travel between rooms. Additionally, inspired by existing tutorials and pictures online we modelled a monitor, USB storage device, desk, and box for cyber unsafe objects, see Figure 1. These objects all had an in-game function. The screen stands on the desk and plays a central role in the password task. The USB storage device, the desk and the cyber unsafe objects box play a role in the USB task.

Figure 1: Office objects; From left to right: Screen, USB storage device, desk, box for cyber unsafe objects

Besides objects we had four characters, one for the player and three non-player characters. The first avatar is the players', partially visible in the VR environment (e.g. hands) and completely when they would look into a mirror. We choose to use a single avatar over the participant choosing one out of multiple, since the time needed to understand that interaction (and accompanying experience of switching bodies) to us felt too distracting. The second set of avatars included two security officers in an IT-department room, both a male and female, sitting at their desk and looking at their screen and then looking around, typing, blinking with their eyes, see Figure 2. Upon entering with the USB device, the female character was triggered to point at the cyber unsafe objects box, see Figure 1. The third avatar was a character which walked in, representing a friendly colleague, who plays a role at the beginning of the USB task. The character informed that he found a USB storage device in the hallway and put it in the top drawer of the desk. The animations of the characters were made using Blender.

To steer the user through the environment, we guided the user with a floating virtual canvas in the office. This screen is displaying the current task for the participant. An example is to meet Susan in the IT-department or to move the plant from one location to another. This helped the participants that were new to VR to get used to the controls. Moreover, to overcome that users would get stuck in a task, a timer was implemented. When the time was up, the participant is informed and had to move on to the next task.

Having a VR environment without any sound can distract the participant since they can hear the surroundings from the physical realm. To overcome this, background traffic sounds were included. For the IT-department office, instead we included office background chatter.

To show content on the computer screen, which we needed for the password task we used a canvas layover attached to the screen that can show text on images. Based on the status of a button in the game, a certain flow is triggered and can display various screens (e.g., a change password screen).

Figure 2: Fully decorated office

The learning objective of the password task is to get to know what good passwords are and the importance of enabling multi factor authentication. Therefore, the user performs tasks which test their knowledge on passwords. It starts with the user turning on the computers. Secondly, the user should change the password. When this task would let users insert their own password there is the potential danger that they fill in one of their current passwords, this would be ethically irresponsible. In order to simulate this action, but remove the included danger, it was we implemented a multiple-choice option. The multiple-choice options include both strong and weak passwords. The third step focuses on multi factor authentication, the computer will let the user choose to enable this multi factor authentication. The timing of information for the training can either be as instructions or in the form of feedback on choices. As we were afraid pausing the task of the user to provide feedback would interrupt them too much and only had a short overall interaction, we provided the feedback on both the password and USB tasks simultaneously at the end of the whole interaction. For the password this included the text *"Password management is an important aspect in cybersecurity. A strong password consists of over eight characters, including both alphanumerical and special characters. Furthermore, one should never reuse passwords from other accounts. A possible way to create such a strong password is the use of a passphrase."*. And for the USB task it read as follows: *"Removable media such as a usb can contain malware that can be installed on your computer when you plug it in. Therefore, you should always safely dispose of unknown removable media. For example, by handling it in an at the IT department.*

5. Method

The evaluation of the environment was tested using a pretest-posttest design. The Human Aspects of Information Security Questionnaire (HAIS-Q) was used to assess participants' knowledge, attitude, and self-reported behaviour (Parsons et al., 2014). The System Usability Scale (SUS) was used to measure usability (Brooke, 1995).

5.1 Participants

The pool of subjects in this research were university staff members, students and acquaintances of the authors. All were recruited via direct contact or in the case of staff members via a colleague. Those that are prone to motion sickness are advised not to participate in this study. In total 16 people participated in this study. Half of the participants indicated to be female, and the age ranged between the 18 and 65 yo. There were 10 (62.5%) participants in the age group 18-35, the remaining participants were older. Finally, there were 8 (50%) participants who completed a university bachelor or master.

5.2 Materials

The VR environment as described in Section 4 and loaded onto an Oculus Quest 2 Business Edition headset, running software version 37.0. The supporting laptop ran Windows 10 with an NVIDIA GeForce RTX 3050 graphics card. For validation, the Human Aspect Information Security Questionnaire (HAIS-Q) was used to measure information security awareness (Parsons et al. 2017). The underlying KAB model uses Knowledge, Attitude and Behaviour to measure awareness. Thereby assuming: if knowledge increases, attitude can be improved and eventually an improvement of behaviour. The scale consists of 63 items (based on 7 focus areas, each with 3 sub-areas, having 3 items (one for Knowledge, Attitude and Behaviour)) to be measured using a 5-point Likert scale, with answer options ranging from 'Strongly disagree' to 'Strongly agree'. Sample questions include: "It is a bad idea to share my work passwords, even if a colleague asks for it" and "I use a different password for my social media and work accounts". A study among 500 Australian employees showed an internal consistency of .88, .88 and .91 for Knowledge, Attitude and Behaviour, respectively (Parsons et al. 2014). These alpha values are in the range 0.8 - 0.9 and are considered 'good'. Within our study we only used a subset of the HAIS-Q, limiting to the relevant focus areas. For the password management focus area of the HAIS-Q there were 9 questions ($\alpha = .75$), the dropped USB focus area consisted of 3 questions ($\alpha = .81$) and the overall scale of 12 questions ($\alpha = .71$) which is considered as 'acceptable'.

To measure the environments' usability, the System Usability Scale (SUS) was used (Brooke, 1995). The SUS is often referred to as the 'quick and dirty' tool for measuring usability. While the scale is easy to administer, scores consistent and reliable for small sample sizes. A downside is the complexity of interpreting the score, where people tend to perceive a score between 0 and 100 as percentage (Brooke, 2013). The scale consists of 10 items to be answered using a 5-point Likert scale, with answer options ranging from 'Strongly disagree' to 'Strongly agree'. Sample questions include: "I found the system unnecessarily complex" and "I would imagine that most people would learn to use this system very quickly". Regarding the reliability of the SUS, an aggregate result of N = 2324 SUS survey responses from K = 206 studies shows a Cronbach's Alpha value of .911 (Bangor et al. 2008).

5.3 Procedure

Our research received another positive advice by our faculty's ethical committee. The evaluation used a pretest-posttest design; first, the participants completed 1 round of the HAIS-Q. Since the VR environment only included two cyber challenges (i.e., dropped USB and change passwords), the corresponding focus areas from HAIS-Q (i.e., Information handling and password management) were included in the questionnaire. Second, the participants played in the VR environment and completed two tasks (i.e., cyber challenges). Finally, once more participants completed the HAIS-Q, and a SUS questionnaire.

5.4 Analysis

The increase in knowledge because of participating in the VR environment was tested using a paired-samples t-test. The following 4 assumptions must be met for this t-test: (1) Continuous data; (2) Independent observations; (3) Normal distribution of score differences; (4) no outliers (JMP, 2023). A Likert scale was used to collect data, for analysis we follow our "intervalist" view fitting the idea behind how Likert scales are created and used, and where we assume the averaged *scale* to approximate continuous data (cf Harpe, 2015, Schrum et al, 2020). Although this is hard to test, it is reasonable to assume that the participating employees are independent of one another. A Shapiro-Wilk test showed no evidence of non-normality (W = 0.936, p = .318). Finally, a boxplot was used to detect outliers, see Figure 3, hence we conclude there are no outliers. All 4 assumptions are met and therefore we use a paired-samples t-test.

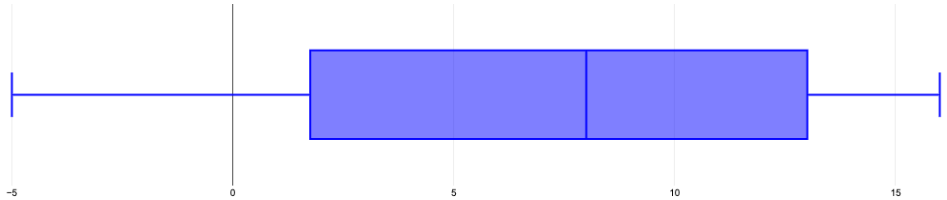

Figure 3: Boxplot for outlier detection on HAIS-Q score difference

6. Results

There was a significant increase in the Knowledge score of the HAIS-Q after the VR experience (M = 54.75, SD = 3.42) compared to the scores before (M = 47.5, SD = 6.31), t(15) = 4.7, p < .001. This translates to a Cohen's d of 1.46 and can be classified as a large effect (Cohen, 2013). For an illustration of the before and after HAIS-Q score distribution, refer to Figure 4. Furthermore, the SUS score (M = 72.5, SD = 8.4) is higher than the threshold of 68 and can be translated to the percentile score of 65% or 'acceptable' in terms of acceptance.

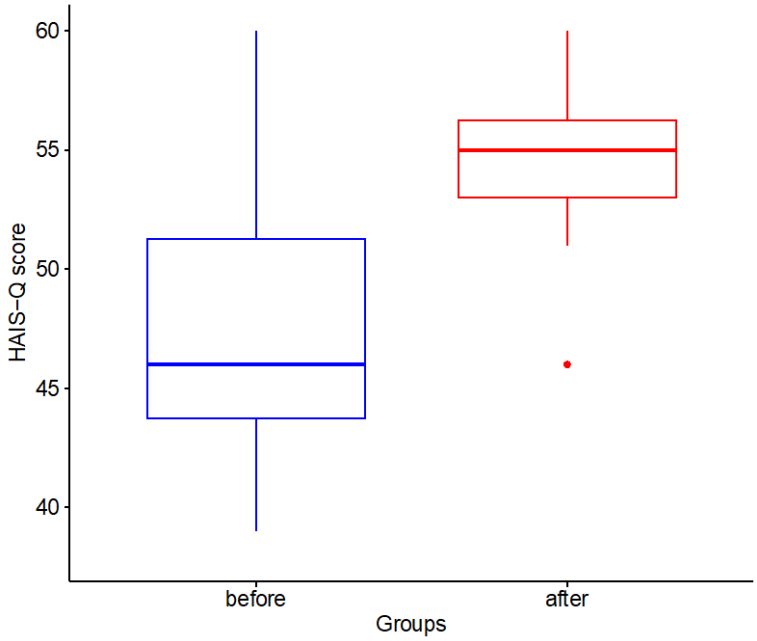

Figure 4: Boxplot for the HAIS-Q scores of the before and after measures

7. Discussion and Conclusion

In this study, we explored the use of IVR for cybersecurity training. Resulting in VRCyberEducation an interactive Social VR world which aims to reduce victimisation of cybercrime among users. We evaluated interaction with this environment on both usability and effectiveness. The study demonstrated a statistically significant improvement in knowledge scores related to information handling and password management among participants who engaged in the VR environment. These results show that using a VR environment can be a promising modality for providing cybersecurity training. Note that the post-test was performed immediately after the VR experience with the feedback close to the end. Previous research shows that these training effects decay over time in similar populations (Bullee & Junger, 2020).

The participants indicated that the usability of the environment, as measured with SUS, was acceptable but also leaves room for further improvement. The limited sample size and convenience sample severely limits the generalisability to a broader audience. Nonetheless, VRCyberEducation can already inspire future research, training for instance the limited sharing of personal information via social media and mobile devices, or the appropriate behaviour of locking doors and computers.

We end this paper with two important suggestions for future research to overcome current limitations: 1) In the current study, a convenience sample of 16 participants was used. First the number of participants can be increased with a homogeneous sample and later with a representative sample of an organisational workforce. 2) The current set-up consists of two cyber challenges. For future research, we plan on extending the environment so that other challenges can be included and to investigate the form and timing of feedback. Furthermore, to make full use of the power of SocialVR the environment can easily be extended to a multi-user environment so that multiple users can participate in real-time simultaneously in a single session. This would allow users to interact with each other and have a discussion.

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An Eye-Tracking Study of GBL Motivators and Learner Behavior

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Abstract: Despite the significant positive characteristics game-based learning offers to pupil learning and assessment, preserving pupils' interest and keeping them engaged in an educational game is still a challenge. To this end, the study and implementation of motivation mechanisms in educational games are considered crucial. Typical examples of motivators in electronic games include points (coins), avatar icons, visualization of achievement levels, NPCs (non-player characters) giving helpful information to users, children-friendly graphics and sound effects, comparison with classmates, and leaderboards. In this paper, we conduct a preliminary study of the effectiveness of these GBL motivators in MG, an educational game for practicing and assessing multiplication skills. The study combined eye-tracking with a short, semi-structured interview session with the four elementary school students that took part in the experiment. Eye-tracking provides detailed monitoring and visualization of gaze behavior in the form of fixation (point and duration of visual focus) and saccade sequences. Given that the way users allocate their visual focus is spontaneous, the data collected and analyzed by eye-tracking are unbiased and give a new spectrum of insight into how users perceive a visual stimulus. In this study, we investigate how users visually respond to the implemented motivators and their visual behavior when deciding between two or more available answers and when given feedback after a wrong answer. The paper discusses useful eye-tracking metrics, provides adequate visualizations of the main findings, and concludes with the ways eye-tracking can help education scientists and practitioners gain a better understanding of the behavior of users of GBL applications and the motivation mechanisms they support.

Keywords: Motivators, Eye-tracking, Total fixations duration, Multiplication, Elementary school, Student assessment

1. Introduction

Motivation has a very important role in learning and achievement and furthermore motivated pupils have better outcomes and perform better (Pintrich, 2003). Motivation can be described as "*a condition that activates and sustains behavior toward a goal*" (Brown, 2007). Motivation can be categorized into intrinsic and extrinsic: intrinsic is produced by internal factors, whereas extrinsic by external factors. Intrinsic motivation exists when a learner has internal desire to perform a task, while will only be rewarded with personal satisfaction and enjoyment (Hodges, 2004). "*Fascination with the subject, a sense of its relevance to life and the world, a sense of accomplishment in mastering it, and a sense of calling to it*" (DeLong and Winter, 2002) are intrinsic motivators. Developing intrinsic motivation leads to student learning while the subject remains in the center of these efforts and not rewards or penalties. Extrinsic motivators exist when a learner is motivated by rewards and incentives external to personal interest and satisfaction (Hodges, 2004). External motivators can be money, prize, grades, positive feedback, the learner's purpose to establish parental satisfaction, the desire for high assessment in an external exam or be best among peers (Ur, 1996; Brown, 2007).

Gamification uses the motivational power of techniques, mechanics, and dynamics of games to support participation, persistence, and achievements. Gamification takes advantage of the combination of both intrinsic and extrinsic motivation: extrinsic rewards for engagement while there are promoted intrinsic motivation features like achieving mastery, autonomy, and sense of belonging (Muntean, 2011). Points, badges, leaderboards, performance graphs, meaningful stories, avatars and teammates are considered to be the game design elements with the strongest effect on motivation (Sailer *et al.*, 2017).

In this paper, we conduct a preliminary study of the effectiveness of gamification motivators in the Multiplication Game (MG), an educational game for practicing and assessing multiplication skills of elementary school pupils (Leonardou, Rigou and Garofalakis, 2019, 2020). In its final development phase (Leonardou, Rigou and Garofalakis, 2020; Leonardou *et al.*, 2022), MG incorporated gamification motivators: points (coins), avatar icon, visualization of level achievements (current and previous), NPC characters giving information, children-friendly graphics and sound effects, social comparison and leaderboards. In the current study, gamification motivators in MG are studied with the help of eye-tracking, which provides detailed monitoring and visualization of gaze behavior in the form of fixation (point and duration of visual focus) and saccade sequences. Given that the way users allocate their visual focus is spontaneous, the data collected and analyzed by eye-tracking are unbiased and give a new spectrum of insight into how users perceive a visual stimulus. In this study, we investigate how

users visually respond to the implemented motivators and their visual behavior when deciding between two or more available answers and when given feedback after a wrong answer.

2. Related work

Mathematics has been a preoccupation of education and pedagogy since ancient times and remains a growing point of interest to this day. It is an essential part of any modern curriculum for developing students' critical thinking and abilities (Shin *et al.*, 2012; Chen *et al.*, 2021; Zhu, Guo and Yang, 2023). In modern times, the goal and implementation of digital technologies is to redefine the roles of the educator and the learner (Chen *et al.*, 2021; Zhu, Guo and Yang, 2023). The utilization of computer technologies for learning and teaching mathematics, naturally, expands the possibilities for student modeling, exploitation of multiple and associated illustrations, dynamic manipulation, and kinesthetic management of what shows on the display. In this context, the added pedagogical value of employing software in mathematics teaching is sought in the structures and relationships that govern students' interactions with digital objects that are designed to be manipulated and favor a variety of interactions between computing tools and all those involved in the teaching practice (Suherman and Vidákovich, 2022; Zhu, Guo and Yang, 2022, 2023). The mathematics that occurs in such circumstances might be regarded as an activity that benefits generative reasoning rather than an established process of implementation of educational materials and instructions. As a consequence, we intend to capitalize on the children's urge for play, helping them to break out from abstract and formal forms of reasoning (Bolden *et al.*, 2015; Hahn and Klein, 2022; Pan, Ke and Xu, 2022). The next issue to address is whether an educational game can respond to these features to form a good instructional support environment. At their finest, games provide an experience with a prominent level of involvement and sociability (Strohmaier *et al.*, 2020; Chen *et al.*, 2021; Hahn and Klein, 2022). To make the shift from traditional teaching to digital game-based learning (DGBL) it is crucial to also support student assessment in the digital environment. In literature, traditional methods of student assessment (SA) are described as self-report surveys, standardized tests, etc. The latest years such kind of methods are widely considered by researchers to cause test anxiety. Furthermore, many times they skip students' thinking processes and are not applicable to assessment in the upper grades' skills. On the other hand, digital game-based assessment (DGBA) offers significant advantages. In (Zhu, Guo and Yang, 2023) characteristics of DGBA studies, as well as the adopted games for SA over the last decade are examined from different perspectives through a systematic review procedure. They found there is a trend towards small sample sizes and that educational games, which are less fun, emerged as the most frequently used game genre. The study of (Chen *et al.*, 2021) investigated the application of game-based learning in science and mathematics education. They found that this application in the particular fields help learners increase their motivation and reduce learning anxiety.

Numerous research efforts have focused on the use of new technologies in the study of cognitive and behavioral/attitudinal change in education and the importance of using non-interventional methods in studies with children. Strohmaier et al., (2020) provide valuable findings that eye-tracking methods are more than beneficial in the studying process, as they help reveal mental representations and assess subconscious aspects of mathematical thinking in students (Strohmaier *et al.*, 2020). Pan et al. made a systematic review of learning games foresting mathematics education specified in K-12 settings. They pointed out that there must be improvements in the design of the games (Pan, Ke and Xu, 2022). Another relevant study, in the field of physics education research showed that eye-tracking methods can help researchers understand the way that a physics problem is solved students and how they learn from it (Hahn and Klein, 2022). In (Fulya Eyupoglu and Nietfeld, 2019) researchers studied motivation factors in game-based learning environments by reviewing studies that have implemented and assessed intrinsic motivation in these kind of games.

Zang et al. conducted an eye-tracking study with 27 participants were grade seven students and separated in high/low groups based on their background knowledge on a particular scientific subject (Zang *et al.*, 2022). The results showed that high achievement students exceed the other group in terms of performance which was indicated in their visual behavior as their eye-movements were highly correlated with the performance. In the more challenging tasks, the average and total fixation duration metrics were higher in the high achievement group indicating greater cognitive workload, while there was a statistically significant relationship between pupil diameter and visual attention on the corresponding key areas of each task (AOIs).

Yuhana et al. investigated a puzzle serious game for the learning assessment of basic arithmetic operations (Yuhana, Sulistyani and Husniah, 2023) with an experiment that recruited thirty five students between the ages of 11-12. The majority of students revealed that they preferred the game to other classical examination methods, with the results indicating that the game met all the pedagogical criteria it incorporates and scored

high on the technical and playfulness criteria as well but a well-designed and implement serious game framework must satisfy additional conditions for students to fully immerse in the game.

Bolder et al. investigated how different representations of multiplication problems affect children's assessment tasks and visual stimuli by recognizing patterns in eye-movements with eye-tracking technology (Bolden *et al.*, 2015). The experimental design included static pictures with variations in type of representation (groups, array, number line), orientations of calculations (traditional, lots of) and whether the picture matched with the dimensions of the calculation (match, above, below). The results from nine youngsters (9-10 years old) revealed a statistical difference in the successful responses across the various presenting methods, with groups and arrays performing superior. Heatmaps revealed that the youngsters with the highest success rate utilized the counting groups approach, the counting axes method in arrays, and the last digit of the number line in number lines.

Conati et al. introduced Prime Climb (Conati, Jaques and Muir, 2013), an educational game for youngsters to familiarize with factorial numbers, and tested it using eye-tracking. This study incorporates different types of adaptive hints (bottom-out, definition, tool) throughout the gameplay experience to evaluate the student's performance, attitudes, and timing in accordance with the hints. The results from thirteen students (grades 5,6) indicate that there is strong positive correlation between attention to hints and correctness of actions, (i.e., game performance without leading to cognitive distraction of players) while fixation time was increased for students in need of help. When the number of fixations was reduced throughout the second part of the game, the timing of each hint was discovered to influence the visual stimuli and concentration capabilities of the users.

In (Hung, Huang and Hwang, 2014), the authors developed a mathematics mobile game based on e-books to investigate how different teaching approaches effect learning achievement. To identify these differences, 69 5th-grade students were divided into three groups based on their learning styles (digital game-based learning, enhanced-technology learning, and traditional) and answered questionnaires on self-efficacy, motivation, and mathematical anxiety prior to and the experiment. The findings revealed that, in comparison to the other two methods, the traditional practices raised students' learning anxiety while simultaneously failing to deliver better learning outcomes. In contrast, DGBL and e-learning techniques were found to have a substantial impact on self-efficacy and a favorable association with learning motivation.

In (Cutumisu *et al.*, 2019) researchers conducted an experiment in which they studied the visual behavior of university students on critical and confirmatory written feedback while they are playing a poster-design digital game. The main hypothesis was that users dwell longer on critical than on confirmatory feedback. The eye-tracking metrics used to evaluate the results were: a) dwell time of participants when feedback revisits were discounted b) mean number of gaze fixations different between valences of assigned feedback c) difference of mean number of feedback revisits between feedback valences of assigned feedback. This paper brings evidence to support the use of eye-tracking for learning processes over behavioral methods alone to investigate feedback processing as well as to understand the precise factors that lead to a deeper processing of critical feedback.

Eye-tracking has been used in various educational settings including architecture for researchers to understand through their students how they perceive the changes in the field of architecture (Rusnak and Rabiega, 2021), in the industry of manufacturing engineering while students and workers communicate in a problem-solving scenario (Vijayan, Mork and Hansen, 2018), and in chemistry to measure students' visual attention while solving word problems in the scenario of blended learning problems(Tucker Blackmon and Castillo, 2019). Besides different educational domains, eye-tracking has also been used for various user groups. For instance, (Chan *et al.*, 2022) investigated whether eye-tracking training can enhance learning and memory of children with learning difficulties as there is evidence that children who received eye-tracking training showed improved attention and inhibitory control. Children who received the eye-tracking training, showed significant improvement in memory and significantly faster learning.

3. Methodology and Purpose

The experiment was conducted at a well-equipped usability engineering lab (University of Patras) and users were recorded while playing the MG with a Tobii T60 eye-tracker, while collected data were visualized and analyzed with Tobii Studio. The eye-tracker is built into a 17-inch TFT, 1280x1024 monitor and offers an accuracy of 0.5 degrees. Four young pupils took part in the experiment, two boys and two girls attending the 2nd, the 3rd and the 4th Elementary School grades. Two of them (2nd grade pupils) were asked to play the multiplication game with all the numbers (multiplications tables 1-10) twice to study whether the game is fun or tiring for players. The other two (3rd and 4th grade) were asked to select and play with just the more difficult numbers (multiplication

tables of 3, 6 and 9 are considered the most difficult). The purpose for this discrimination was to test all pupils at an 'equal' level of difficulty depending on their grade (skills level).

The game that was tested (MG) includes four consecutive levels with a fixed number of random questions, namely level 1 with True/False questions, level 2 with multiple choice, level 3 with drag-and-drop (players match the question with the answer) and level 4 where players must type the answer. Regarding the incorporated motivation mechanisms, players can select an avatar, collect coins when giving a correct answer, and when completing a level can see the progress achieved so far in textual and visual form (smiley faces, simple quantized representations suitable for primary school ages (Bull and McKay, 2004)). When completing a game session, the player can be informed through bar charts about the overall accomplishments (how well they performed in each multiplication table) and a Hall of Fame (leaderboard) is presented with the names of the classmates holding the best scores. During the entire playing process friendly animals are used as NPC characters to inform or give advice to players.

The purpose of the experiment was to gain insights about the following issues and the study focused on qualitative (rather than quantitative) data and analysis given the small number of participants:

- Do pupils focus their attention on certain parts of the screen and are those parts the expected ones for the progression of the game?
- After the completing each game level, do pupils notice the option to be informed about their progress before proceeding to the next level?
- How do pupils visually react to feedback after a wrong answer?
- Do pupils notice their score (coins) and how often they check it when playing the game?

After playing the game, the moderator had a small semi-structured interview with each participant to more accurately understand and more objectively interpret their emotional states (e.g. excitement, stress, competitiveness) and thoughts (e.g. doubt about the correct answer) while interacting with the game.

4. Collected Data and Discussion

From the inspection of gaze plots, heatmaps and cluster plots it is evident that pupils focused their attention to the important (and expected) parts of the screen depending on the level of the game they currently play (the type of questions). For instance, as depicted in Figure 1, both 2nd grade pupils focused their attention to the main elements of the screen i.e., the equation and the answer section. The difference is that the boy also fixated a fair amount of time on his coins area thus demostrating a more competitive behaviour. Gaze plots specifically revealed that players made many fixations on the area of the equation and even more on the area of answers which denotes cognitive processing (Figure 2). Another general observation is that at level 4 pupils made more fixations on the question area as at this level they had to calculate and type in the answer and not select it from a set of given answers. In addition, they had to drag and drop each ball/answer (on the bottom part of the screen) on the correct basket/question (on the upper part of the screen). Heatmaps and especially gaze plots (and their animated replay) provide another useful insight: we can observe whether they had difficulty deciding what to choose (and in the case of gaze plots we can also see in which order pupils saw the answers).

Observations from the second group of pupils (grade 3rd and 4th) are quite similar but we recorded lower fixation numbers, as pupils are much more confident about the correct answers. Also, they fixated on visual elements on the screens that attracted their interest (such as their avatar, or the NPC and the sports equipment on each scene), which could also be explained due to their familiarity with the main task (multiplication) which allows them to look around the complete scene and elements on the screen. These more skilled pupils (in terms of math) also notice more the option to see their progress after completing each level and their score compared to their peers. Regarding feedback on wrong answers, they demonstrate less fixations with smaller durations as they only need to be reminded of the correct answer and do not try to confirm it by calculating (which seems to be the case for lower grade pupils).

Table 1 depicts the average TFD (Total Fixation Duration) calculated for the defined AOIs of multiplication equation (question), available choices for the player to select (answers) and the score (coins). The value of this metric depends on the level as each levels offers different types of questions in an ascending order of difficulty according to the designers of the game. Still, eye-tracking data reveal a slightly different story as pupils seem to have spent on average more time fixating at level 3 (74.28 sec), then at level 1 (51.26 sec), then level 4 (44.42 sec) and then level 2 (42.61 sec). Based on the type of questions on each level, the hardest type of questions is drag-and-drop where pupils had to match four multiplications with their answer, and true/false questions of

level 1, which comes as a surprise since this question type is considered relatively easy. One possible explanation is that it is the first level of the game and users are not yet familiar with the user interface and the quiz mentality. As observed in Figure 3, players made the most fixations on the question at hand in level 1 (67% of total fixations duration) and level 4 (87% of total fixations duration). This is expected based on the typology of these questions (the player does not need to examine and select available answers).

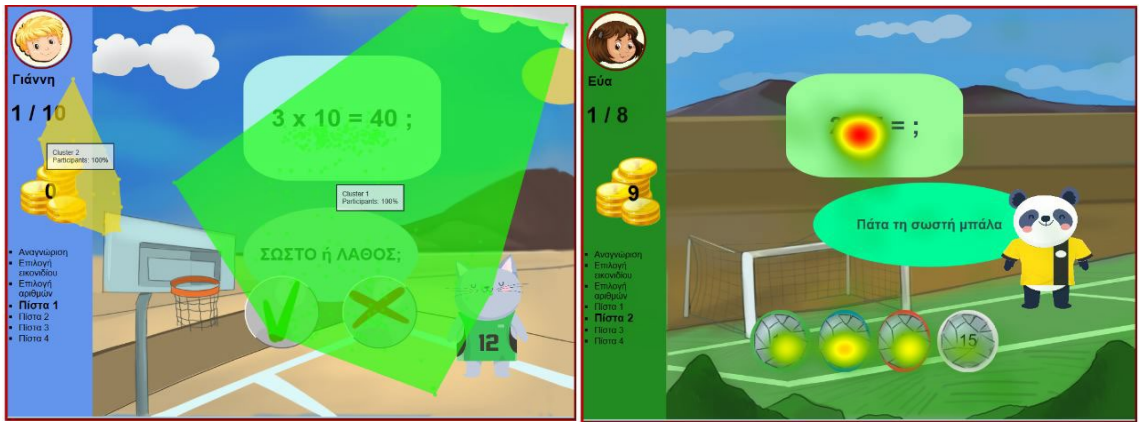

Figure 1: Cluster plot from the boy's interaction at level 1 (true/false) on the left and heatmap from the girl's interaction at level 2 (multiple choice) on the right

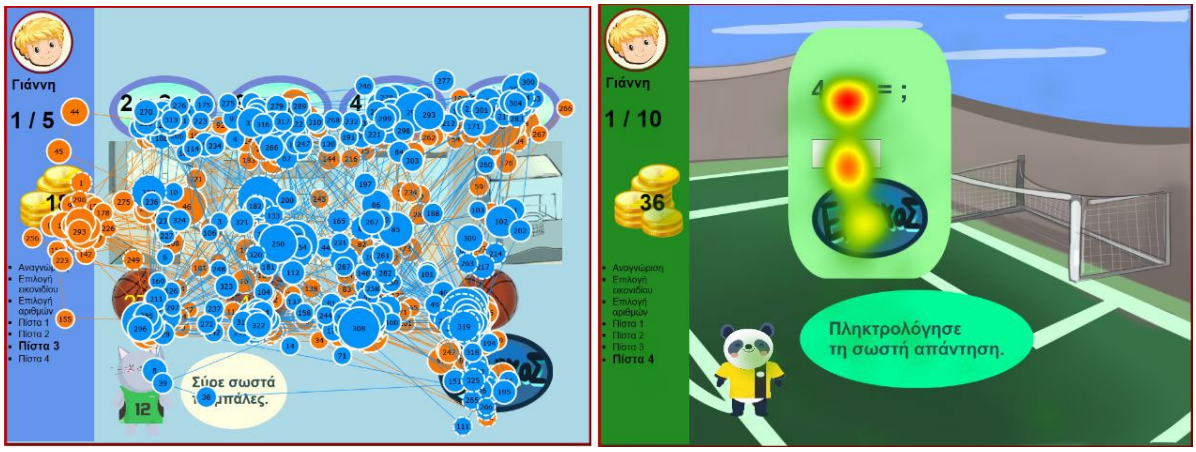

Figure 2: Gaze plot from two game sessions from the boy's interaction at level 3 (drag-and-drop) on the left and level 4 (type the answer) on the right.

Table 1: Average TFD (Total Fixation Duration) for AOIs in each game level

AOIs	Level 1 (true/false)		Level 2 (multiple choice)		Level 3 (drag-and-drop)		Level 4 (type the answer)	
Equation	34.57	67%	16.66	39%	38.69	52%	38.62	87%
Choice	13.55	26%	23.87	56%	30.99	42%	-	
Score	3.14	6%	2.08	5%	4.60	6%	5.80	13%
Total	51.26		42.61		74.28		44.42	

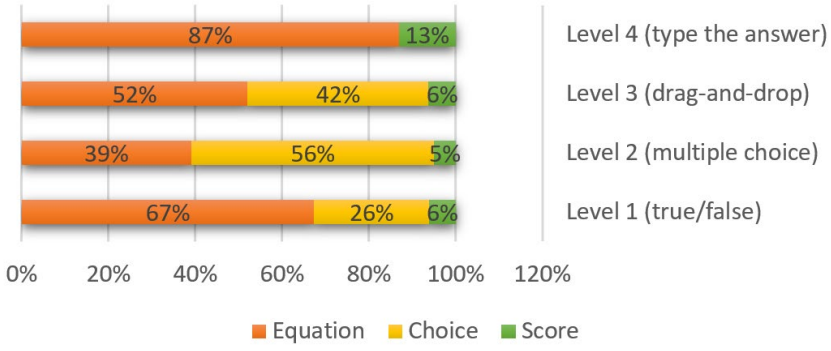

Figure 3: Percentage of TFD on each AOI (i.e., equation/question, choice/answer, and score/coins) per game level

The short interview sessions that followed each eye-tracked game session confirmed that players regardless of age and multiplication skills liked testing their knowledge through the game. More confident players kept their attention to their score and did not need to concentrate mush on the feedback when giving a wrong answer, which differentiates them from the less confident players. An interesting observation by the 4th-grade pupil is that he already knew multiplication very well so for him the game did not have much educational value, but he believed that if he could use the game in 2nd and 3rd grade then it would have helped him learn multiplication tables faster. This is an interesting assumption that needs to be confirmed by testing groups of pupils in the 2nd and 3rd grades that will regularly use the game and compare their progress to respective control groups.

Interviews also confirmed that the younger players did get indecisive in certain questions and could not choose between two or three answers, an observation we made based on the eye-tracking data. According to players, the most noticed motivators were the coins, the leaderboard and the NPCs. They also liked the overall design of graphics and embedded sounds but would prefer being able to choose their theme of preference at the beginning of the game. Also, multiplication skilled pupils would like it if a fast correct answer gave them more coins than a slow correct one.

5. Conclusions

The paper presents a preliminary study of the visual behavior of elementary school pupils when interacting with MG, an educational game for practicing and assessing multiplication skills, which incorporates various motivation mechanisms. The purpose of the experiment was to examine how eye-tracking can be integrated into user testing and reveal additional findings regarding specific game design elements and user visual behavior in terms of learning through playing. Findings indicate that pupils noticed, used and liked coins, the leaderboard and NPCs. Eye-tracking offered information about questions that puzzled pupils, pupil behavior towards feedback on wrong answers and level of pupil competitiveness. Overall participants with different level of multiplication skills behaved differently as regards coins and feedback on errors and they also expressed different opinions about motivators when interviewed. This is an issue that should be further investigated to reach solid results that can guide educators and game designers towards selecting and incorporating a suitable set of functionalities and motivators in educational games. Moreover, factors other than skills may affect this decision (such as player gender and personality).

The primary limitation of this preliminary study is that it is based on the observations of a small user group, but it is starting point to prepare for a future expanded test that will include more pupils and a longer testing periods. According to the related bibliography, 39 participants allow for quantitative analysis of collected eye-tracking recordings, but qualitative analysis can be done with less than 10 users. Considering the additional insights eye-tracking can offer, it is a practical choice to incorporate it in user testing even if just for a small subset of the user group.

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The Race to Nuclear Supremacy: Classroom Games as Motivation for Student Learning

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Abstract: The use of games in education is applied in classroom settings from all academic levels. More importantly, games can motivate student learning in courses that depend heavily on evaluation and comprehension. The number of digital games available to enhance learning outcomes while motivating student-learning are overwhelming. Nonetheless, access to such content can be costly and limited to academic institutions that lack funds and technology. In this paper, we analyzed how a set of magnetic spheres paired with games motivated student learning in courses across 2 multicultural classrooms (Physics and Social Studies). By designing a session about the atomic bomb in a history course, professors from both History and Physics used a set of small magnetic spheres and Albert Einstein's equation E=mc2 to complement student learning in a history classroom to comprehend a topic, by using components of the magnetic spheres as an analogy of the nucleus of an atom, where the magnetic force between spheres represents the weak nuclear force. We explained the nuclear fission phenomenon and the history behind this discovery in a more hands-on approach. With this analogy, a game was designed, in which students after having taken a lecture on the history of nuclear fission and an overall explanation of Albert Einstein's formula, simulated building the atomic nuclei of radioactive elements by adding a pair of neutrons to quantify the energy released when separated as individual particles. After completing the game-based activity, we conducted a series of surveys among students to 1) analyze students' perception of the learning process during multidisciplinary classes with classroom games and 2) identify attitudes towards subject comprehension through classroom games. The experiment was carried out in sessions of 50 minutes per group. The participants of the case study were students from a private education institution in the northwestern region of Mexico (State of Sonora). We examined how these game-based activities were perceived by the students regarding their motivation to learn. In order to enhance the motivation for student learning, multidisciplinary collaboration should be included in the design process of the curriculum the school offers to its students.

Keywords: Higher education, Educational innovation, Game-based learning, Social studies, Nuclear fission, Tec 21 Educative Model

1. Introduction

Educational institutions and professors around the world have strived to provide a quality education for their students at each academic level. The standard that these must meet is not only to respond to international organizations, national authorities, and experts but to students as well. The challenges that the education system has endured during these last few years due to the global pandemic, and the remote learning environments among other difficulties have had a lasting impact on how students receive their information and on how professors must meet them in the middle.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the education systems do not present the necessary tools, connectivity nor technical skills, and competencies that the digital age requires for the fast-paced globalized post-pandemic world of today (2023). In the case of Latin American countries, one of the expected targeted goals out of the 17 Sustainable Development Goals (SDGs) is Goal #4: Quality Education, which looks to achieve inclusivity in education and learning opportunities for all around the world and across different academic levels.

Critical thinking skills, which are promoted in Social Sciences, and Mathematics (which are aligned with physics courses); the United Nations reports that "6 out of 10 children and adolescents are not achieving a minimum level of proficiency" (2023) in such competencies. By including methodologies in the learning process that aim to motivate and engage student learning, such SDG can be achieved by 2030 with the aid of professors and institutions alike.

An experiment has already been carried out in which game techniques and project-based learning methods were used during a physics lecture in a group of 34 9th-grade students to examine the impact these games have on their physics achievements, which was measured through tests, and a questionnaire (Baran, M, et al., 2018). The experiment was conducted over a period of 5 weeks in which students had to design game tool projects according to a designed topic. The group was divided into an experimental group consisting of 21 students and

a control group consisting of 13 students. Before the experiment, no significant difference was found between the experimental and the control group in terms of knowledge. However, after the 5-week period, an end-test was administered, and it was determined that students who participated in the experiment achieved significantly higher scores than those who did not participate.

Some factors that affect students' performance are the lack of interest in learning, the reduced number of hours that STEM programs offer, and the lack of resources available such as laboratories and learning playgrounds to promote engaging learning activities.

In order to understand what drives a student's desire to learn so it's possible to propose a new educational system, we conducted research to analyze two factors: the student's perception of the learning process using classroom games in multidisciplinary classes and the students' attitudes towards comprehending the subject via games. The experiment was conducted on 50 students, which were separated into an experimental group of 25 students and a control group of 25 students. The control group was given a lecture on the nuclear fission phenomenon, a brief explanation of Albert Einstein's formula (E=mc2) and how to quantify the energy released, given several atoms and calculating their mass. The experimental group, besides the theoretical lecture, was also provided with a set of magnetic spheres to simulate the construction of an atomic nucleus in order to analyze how it would influence the learning process while being taught physics through a game.

This is a challenging task because even though students have displayed more motivation towards learning when exposed to games during a lecture, sometimes it is hard to conduct these experiments due to the time constraints and lack of economic resources to provide the students with the appropriate games and learning tools and it is necessary to have the required means to help students grow more enthusiastic towards learning STEM-related topics.

2. STEM Education in Mexico

In Mexico, Science, Technology, Engineering, and Mathematics (STEM) sciences are part of the basic education curriculum (primary, middle, and high school). However, the distance between innovation, research, and science development and the education system is increasing. This is due to several reasons, being one of them the low number of students with quality performance in sciences, which can be explained by the decrease in hours that STEM sciences, the lack of physical laboratories in schools to promote such sciences and experiments, the implementation of age-old methodologies that continue to produce a low number of higher education (HE) student, among other aspects (Flores-Camacho, 2012). He notes that it is not only a student-performance problem in the sciences and multidisciplinary skills, but it becomes a research production one (or lack thereof); where the scientific community continues to grow in age and not in number due to the low amount of human capital that is formed and stays in the country.

The country has attempted to increase the number of students motivated to begin a career in the STEM sciences. For example, in 2011, the *Secretaría de Educación y Cultura* (SEC) began a program called *"Síguele, caminemos juntos"* in public high schools across the country. The program's target was to promote and accompany students in their decision-making toward their undergraduate studies in a STEM field. It aimed to promote the participation of girls in sciences as a vocation in the country (Macias Gonzalez, Sánchez Carracedo & Salán Ballesteros, 2021). According to UN Women (2022), women represent less than half of the population that studies a STEM career in Higher Education. In Latin America and the Caribbean, the presence of women in STEM is still the minority in most of the fields. In the case of Mexico, they are also the minority in the scientific community and the *Sistema Nacional de Investigadores* (SNI) as well. In summary, Mexico lacks participation in STEM sciences due to several factors and to the lack of motivation and/or guidance that mostly occurs in the formative education levels of students.

There are several dilemmas that science and research face in the country, but we are only tackling one in our study: how to promote, engage and motivate student learning in multidisciplinary courses by using educational games. By doing so, we aim to motivate more students to engage and explore STEM areas as possible undergraduate studies in Mexico.

2.1 Classroom Games

Whitton & Langan (2019) have mentioned that the 'seriousness' in a student's academic trajectory becomes higher and the creativity and playfulness of learning decreases. Such seriousness can become a limitation to creativity, innovation, and motivation. Álvarez-Herrero and Valls-Bautista (2021) also explored classroom games in a science setting. Creating stimulating and playful learning environments can be inviting to students to engage

more in their learning process. However, the authors also note that there is a discussion if there need to make seriousness and playfulness, especially at a HE level (p. 9).

Wiggins previously noted the importance of further research to identify in what capacity classroom games can enhance motivation among HE students (2016). He pointed out that gamification and game-based learning should be thoroughly researched and promoted to increase interest in STEM areas. Such game-based learning can be seen as an integral part of the curriculum or as an added element to aid in the learning process at the HE level. Most classroom games nowadays are located on digital platforms or online. We understand that most students are capable and well-versed in digital games but most schools in Latin American and Caribbean countries do not have the proper funding nor infrastructure to obtain such equipment, teacher training, or licenses to implement them in their classrooms. In the case of Mexico, public high schools and HE institutions also lack such equipment and proper skills from professors to handle, design and conduct their courses through or with the use of them. In some cases, even private institutions do not have enough resources to fund such technology, nor do they consider classroom games as part of their academic activities. However, the learning process goes together with play, creativity, and imagination.

When referring to multidisciplinary courses or activities, the use of digital games in Mexico is very limited. The use of virtual classrooms, which was put to work during the global pandemic caused by Covid-19, has been previously introduced to HE students. However, the implementation of digital classroom games continues to be limited due to several reasons (lack of funding is one of the main reasons). In the case of Mexico, to implement classroom games educators must think outside of the box and use the resources they have available to them (whether they are physical material, creativity, or funding).

2.2 Student Motivation

For the Organization for Economic Co-operation and Development (OECD), student motivation can lead to better overall outcomes. It states:

> *"Motivation to learn is another very important ingredient of achievement, both in school and in life. In many cases, individuals with less talent (...) are more likely to succeed than those who have talent but are not capable of setting goals for themselves" (2016).*

For Jääska (et al., 2022), student motivation at a Higher Education level is a critical component that needs to be seen from diverse perspectives, since it touches on various actors and key components. For Liu, Bridgeman & Adler (2012), student motivation does have a positive impact on students' academic performance. In sum, it does matter how HE institutions provide the proper tools and environment so they can achieve positive learning outcomes.

3. Methodology

In this qualitative study, we used an exploratory approach to analyze students' perceptions regarding the use of educational games in a multidisciplinary setting. In addition, we used Franco-Mariscal, Oliva-Martínez, & Almoraima Gil's (2015) statements from their validated survey on students' perception of the use of educational games in a chemistry course. We modified them to include multidisciplinary courses (Physics and Social Studies). Since the session included information regarding the use of some periodic table elements (Uranium and Plutonium) and some basic equations, our session consisted of several parts from other disciplines as well (Chemistry and Mathematics).

We conducted the same activity in two different groups with variations: in group 1, students only had the multidisciplinary session and had the activity of solving equations without the educational game; meanwhile in group 2, students that the multidisciplinary session and the activity of equations and the added element of the educational game with the magnets to represent the protons and neutrons. In both groups, students worked in teams of five to collaborate on the quantifications. In addition, the students from both groups also compared the calculated energy to the detonation energy of one kilogram of dynamite. This to know how many times greater is the fission energy concerning the destructive capacity of dynamite.

Both groups were formed by second-semester high school students from a private institution in the northwestern region of Mexico, in the State of Sonora. Tecnologico de Monterrey is a private university based in Monterrey, Mexico. Tecnológico de Monterrey was founded on September 6 in 1943 by Eugenio Garza Sada who obtained a bachelor's degree in civil engineering from the Massachusetts Institute of Technology (MIT). According to Qacquarelli Symonds (QS) Latin America University Rankings 2023, Tecnologico de Monterrey is Mexico's number one university and fourth in Latin America. The institute was evaluated among 429 universities

from across 20 countries and has been ranked number one in Mexico for four consecutive years with a score of 94.7 out of 100.

The institute implemented a new education model named Tec 21 Educative Model during the 2019-2020 period, which is a challenge-based model. It is also a very flexible model which allows students to explore different fields of study and specializations.

In our study, Group 1 consisted of 21 participants, while in Group 2 there were 19. In Group 1, 11 participants were female and 9 were male; while in Group 2, 2 were female, 18 were male and 1 participant preferred not to disclose gender. In total, 13 participants identified as female, 27 as male (the majority in the study), and one did not disclose.

The proper consent forms to participate in the study were provided via email, as well as a disclaimer where it stated that their identities would not be revealed, nor would their answers affect their grade performance in any way whatsoever.

To create the activity, we considered the prior knowledge students had of physics (middle school education) and included in our activity a brief review of the periodic table and its elements, specifically the ones that were used to design the first atomic bomb (Uranium and Plutonium). The activity consisted of understanding the nuclear fusion phenomenon from its origins. This meant that the activity consisted of three parts. First, we provided historical information about the World War II period, the actors, the motivations, the interests, and the alliances that were formed. This part also touched on the historical side of the main physicists (Lise Meitner and Otto Hahn) involved in the discovery of the elements, the formulation, and the creation of the atomic bomb.

The second part consisted of explaining the nature of the chain reaction known as the atomic bomb. This was done by providing an insight into the academic contribution of the work done by Albert Einstein (1905) on the relation between energy and mass (to quantify the fission energy in the separation of the atomic nucleus). Finally, the third and last part was the actual activity that students (in teams) needed to do. In this part, students had to convert the atomic mass of the atom of Uranium or Plutonium to kilograms, thus using it Einstein's formula. To do so, we provided an explanation and an example of how to convert the mass to kilograms. Once the first two parts of the activity were presented, students had to complete the last part in teams of five participants.

Both groups had their sessions in the same week. Group 1 had their activity at the beginning of the weekday (on a Tuesday) and Group 2 was in the middle of a weekday (on a Thursday). In Group 1, the activity consisted of two moments: one was the historical and physics aspect of the explanation of the atomic bomb of World War II; while the other moment was the quantification of the fissionable mass of one group of atoms (Uranium or Plutonium). In the first group, we did not introduce the educational games aspect into the session.

In Group 2, the same two moments as of Group 1 were applied. Nonetheless, the educational games aspect was introduced in the second moment with a magnetic sphere kit to simulate the construction of an atomic nucleus. The kit was chosen to represent the physical interactions that occur in a nucleus of an atom. The force of magnets represented the nuclear force between protons and neutrons. Meanwhile, the colors of some of the magnets represented electric charge (in the case of protons) or no charge (in the case of neutrons).

4. Results and Discussion

We analyzed the information from the students retrieved from the survey we designed to analyze students' motivation and their attitudes toward the use of classroom games in a multidisciplinary environment. In this case, such an environment was made up of the disciplines of Physics and Social Sciences (history).

The target of the activity was to offer students the scientific and historical context of a transcendental event in the history of mankind, such as the atomic bomb, and the technological development of the world. By doing so, we wanted to comprehend their perception regarding multidisciplinary classes with classroom games and analyze the attitudes they had towards subject comprehension by way of classroom games. We are convinced that knowledge can be better approached when tackling problems or situations from a multidisciplinary perspective, regardless of the difficulty of the subjects of study if the student is adequately motivated towards active learning. In the results reported by Herbert James Banda y Joseph Nzabahimana (2022), they argue that by using technologies like simulations for physics teaching students will become more motivated to learn, which leads us to discuss the contribution of this work, since implementing a low-cost game without the need to use a technological application, we obtained extremely positive results regarding the motivation and perception of our students. On the other hand, Christina A. Bauer, Veronika Job & Bettina Hannover (2023) state that there is

a social and cultural bias in first-generation students where they are less talented. However, the idea that success should be measured by work and not only by innate abilities is stated, also mentioning that for the teaching-learning process, it is fundamental to be able to create a great motivation for teaching these subjects since we strongly believe that science is universal and that neither the social conditions nor cultural conditions matter, but the motivation that we consider necessary does.

4.1 Students' Perception of the Learning Process With Games in the Classroom

Regarding the students' perception, statement 10 for group 1 (*Educational games can contribute to me seeing physics as an important area in my life*) showed that 12 of 19 participants agreed with it. While 6 fully agreed and 1 was undecided. In group 2, this statement showed that 9 of 21 participants agreed with it. While 8 fully agreed and 4 were undecided.

In the explanation before carrying out the activity, it was repeatedly mentioned that the race to dominate nuclear energy was not only the development of a destruction bomb but also a new way of producing electrical energy, through the process of the operation of nuclear reactors. This action had an impact on the development of emerging technologies for the processes of burning fossil fuels, which gave strength to the results obtained in this question.

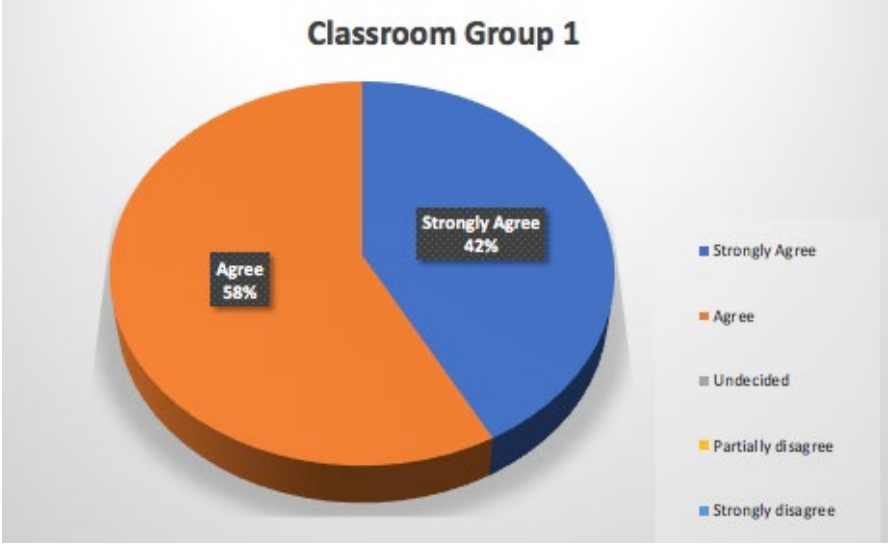

Figure 1: ***Pie chart representing answers from statement 10 (*****Educational games can contribute to me seeing physics as an important area in my life)** ***from participants of Group 1***

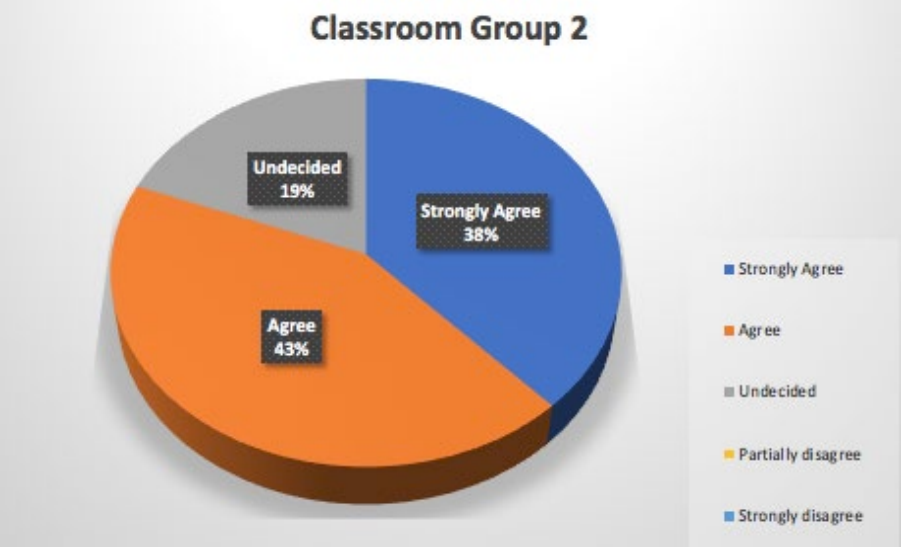

Figure 2: ***Pie chart representing answers from statement 10 (*****Educational games can contribute to me seeing physics as an important area in my life)** ***from participants of Group 2***

On the other hand, statements 1 and 3 for group 1 (The use of educational games makes it easier for me to study, educational games have helped me to gain a better understanding of the multidisciplinary topic) were very positive, showing that 12 out of 19 participants were in total agreement and 7 agreed in statement 1. While, for statement 3, 9 participants were in total agreement and 9 agreed, leaving only one undecided participant.

Now, analyzing statements 1 and 3 for group 2, 10 participants stated that they agreed, 10 stated that they agreed, and 1 participant was undecided regarding statement 1 (The use of educational games makes it easier for me to study). While for statement 3 showing that 8 participants fully agreed, 12 participants agreed, and 1 participant was undecided. This gives us a better idea of the scope and impact they have on perception and understanding among students by introducing activities that invite the use of educational games in the classroom, specifically in a multidisciplinary activity (in this case Social Sciences and Physics).

All survey statements (see Table 1) were represented and analyzed according to our main objectives in this study (see Figures 3 and 4 below).

Table 1: Participants of groups 1 and 2 survey

1. The use of educational games makes it easier for me to study.
2. The educational games had clear and easy-to-follow instructions. Everybody knew what to do.
3. Educational games have helped me to gain a better understanding of the multidisciplinary topic.
4. Because of the use of educational games, I like multidisciplinary courses.
5. I found educational games attractive.
6. I consider educational games to be an appropriate tool for a better understanding of multidisciplinary concepts.
7. I find educational games to be an appropriate way to learn in multidisciplinary courses.
8. By using educational games some multidisciplinary content can be made interesting and even enjoyable.
9. I think that educational games are very entertaining.
10. Educational games can contribute to my seeing physics as an important area in my life.
11. I felt more motivated to participate in classroom tasks when we used educational games.

Table 2: Instructions of exercises for participants

Based on the previous model, determine the released energy produced by a nucleus of a fissile element putting into practice Einstein's formula of the mass-energy relationship. Document the entire calculation process that your team followed to determine the energy. Choose between one of the elements ((Uranium or Plutonium) from the periodic table which will be its object of study.
Determine the energy that would be released by your uranium or plutonium nucleus considering that 1% of its atomic mass was converted to energy.
If it has 10,000 nuclei and that each of them released the energy calculated in the previous part, how much energy would be released by all of them? How much energy would that be compared to the energy released from TNT?

In addition, a statistic was made with the results that we obtained from graphs 3 and 4 (see Figures 3 and 4). For Group 1, the mean values of the 11 statements in Table 1 were obtained: agree 10.1818, strongly agree 7.9090 and undecided 0.9090, while the variability was 3.7636 concerning the mean and with a standard deviation of 1.94. This implies that 18 participants provided positive responses and only 1 participant was within the negative response range. In Group 2, very similar results were obtained with an average value of: agree 9.3636, strongly agree 9.1818, undecided 2.2727, and partially disagree 0.1818. While the variability of these results was 2.8545 concerning the mean and with a standard deviation of 1.6895. This means that a total of 19 participants provided positive answers while only 3 participants provided negative answers.

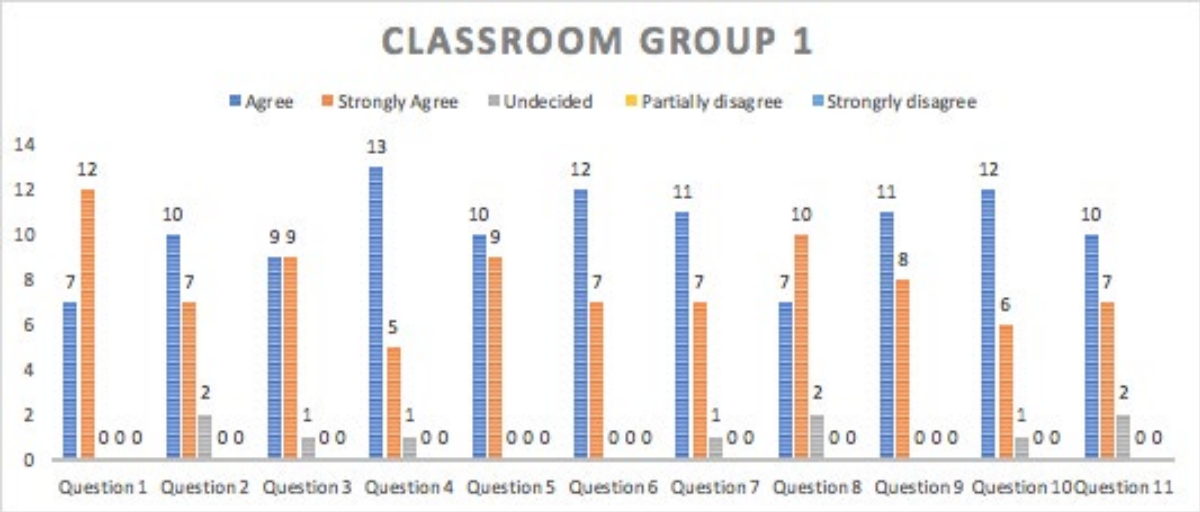

Figure 3: Representation of results of the statements in Table 1 from Group 1

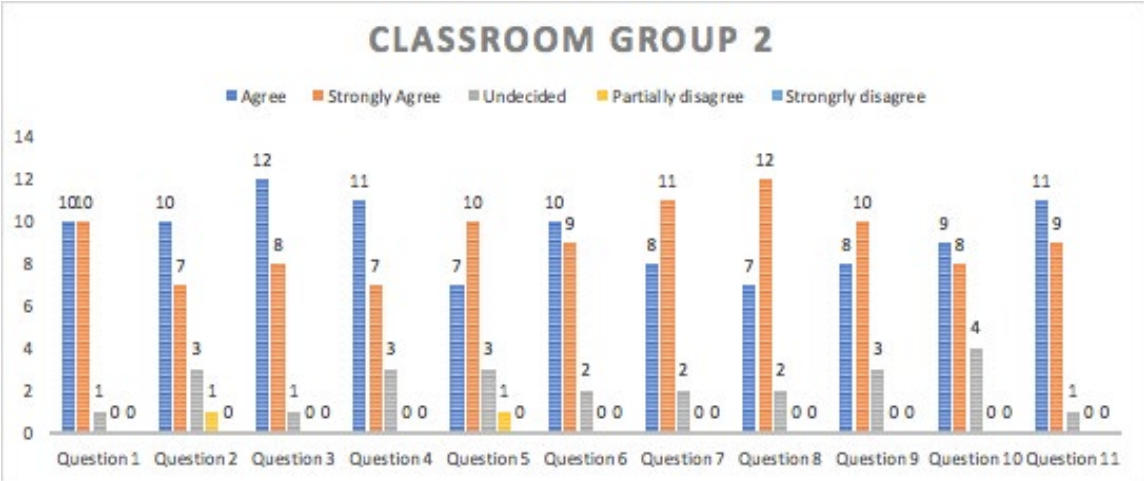

Figure 4: Representation of results of the statements in Table 1 from Group 2

4.2 Attitudes towards understanding the subject through games in the classroom

Regarding attitudes that participants mentioned towards subject comprehension, both groups agreed that the use of classroom games was useful and positive towards their learning process. Even participants from Group 1, who did not use the actual game of magnetic spheres to create the nucleus of an atom, agreed that it would have been good to have such material with them when exploring the subject. Meanwhile, participants from Group 2 had to also represent their model with magnetic spheres (see Figures 5 and 6).

Figure 5: Pictures of the magnetic spheres as an analogy of the nucleus of an atom from Group 2

Figure 6: Pictures of the magnetic spheres as an analogy of the nucleus of an atom from Group 2

In statement 1 of Table 1, 62.2 percent of participants mentioned that they fully agreed that game-based learning aided them in their learning process; and the other 36.8 percent agreed. The possibilities for designing a completely innovative approach towards student learning in the institution emerges: a multidisciplinary course design instead of the traditional course is possible and can be effective among participants.

Statement 2 was fundamental since 36.8 percent of the students agreed that they fully knew what they had to do in the activity, while 52.6 percent agreed with what was being asked to solve and only 10.5 percent were unclear about the explanation. We consider it important due to the complexity of the topic and especially the age of the students. We analyzed their answers from the activity as well as the answers they provided in the survey and determined that their perception of not only the classroom game but the multidisciplinary approach to the lesson was a positive one.

We must note that both groups of participants were given the same information, however, we believe that the activity could have been divided into two sessions per group: one benign that of the historical context and the explanation of the model; and the second one would be dedicated only to the elaboration of the equations and creation of the model itself with the magnetic spheres. This can also change the outcome of students' perception and overall experience with classroom games.

5. Conclusions

In this paper, we analyzed if classroom games in a multidisciplinary environment can motivate students' learning process. Also, we analyzed what attitudes students had toward their learning through classroom games. While we saw overall interest in this multidisciplinary approach to learning with games, only one group of participants managed to 'construct' the model with the magnetic spheres. The initial idea we perceived from the group that did not have a classroom game but only the exercises and the session, was that they perceived the equations as a 'game' or a competition of who can come up with the answers the fastest. However, after questioning the participants on this matter, they did not see the equations as a game but did see them as a fun or playful element of the multidisciplinary session.

The survey conducted was designed to analyze the perception and attitudes of the participants towards learning through educational games, group 1 had a total of 19 responses. The results of the survey displayed that an average of 13 participants agreed and 5 strongly agreed with the statements, while an average of only 1 was undecided. Group 2 had a total of 21 responses. An average of 9 participants agreed and 9 strongly agreed with the statements while 2 were undecided and only a small fraction less than 0.2 disagreed with the statements. Even though group 2 displayed a higher rate of negative responses towards the use of classroom games, we could observe that students displayed more interest at the beginning of the activity. However, their sense of interest began to decrease throughout the development of the activity.

The participants saw the value that classroom games can bring to their learning process, they perceived them as an added component to a session and had a positive attitude overall towards using games to learn and to be motivated in the classroom.

We understand that this does not apply to the overall population of students in an institution but suggest enhancing and modifying our initial study with more proper materials and a two-part session where students and professors alike can have more time to do both parts of the multidisciplinary activity. Also, if necessary, we might add an evaluation of knowledge at the end of such a session to identify if their academic performance on the subject improved, changed, or was maintained with and without the use of classroom games.

The authors of this paper believe that some factors could be corrected and considered more thoroughly when implementing the activity on another occasion, such as using technology (Virtual Reality (VR) or Augmented Reality (AR)). This is to increase the perception, attention, and motivation of learning the current model known as the atomic nucleus. Also, we suggest that activities such as the one described should be implemented among private and public education students to compare the results among both participants.

Declaration of interest

This is to acknowledge that the authors report there are no competing interests to declare.

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Turning Grey to Green: Engaging Gamification in Sustainability Education With Augmented Reality Technology

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Abstract: In recent decades, topics of sustainability and carbon neutrality are getting more attention from society and academia in the sense of urbanization and social innovation. Scholars have been proposing methods to achieve sustainability and they emphasize the importance of educating citizens about the ethics of sustainability. Also, in the educational context, there is a trend in applying gamification concepts to promote sustainability. Previous studies have demonstrated that gamification can engage students through interactive content and reward systems, so that they can be motivated to learn and apply knowledge. Nevertheless, limited articles can be found to propose methods for developing technological applications for green innovation education. In addition, scant interest has been shown to include gamification in sustainability education, especially in Hong Kong. Knowing that simulation games may raise students' curiosity to learn, we designed an augmented-reality-based educational mobile application to investigate their perception of engaging technologies and gamification in the learning process of sustainability education. In this application, there are three major components to be presented. First, various simulation games are included to educate learners with practical skills to nurture sustainable living habits. Cartoons and animations are added to better explain abstract ecological theories, and learners can interact with game characters / elements in real-time motion for an advanced gaming experience. Second, to motivate students to learn the content, digital achievement badges can be earned after winning the mini-games and they can be shared on social media platforms. It is expected that the reward system can attract students to participate actively. Last but not least, the application is hoped to engage Hong Kong citizens and the globe in the Green Deck project of Hong Kong and encourage more social involvement. With reference to the application structure, this study is expected to explore the effects of implementing games and augmented reality on education for sustainable development. Two surveys (pre- and post-surveys) would be established to evaluate the students' learning experience and knowledge acquisition on sustainability.

Keywords: Sustainability education, Gamification, Augmented reality, Social innovation, Simulation games, Green Deck Project

1. Background

Greenhouse effect is a global climate challenge in great concern. With the development of urbanization, an increasing amount of land is being reclaimed for residential areas, leading to fewer green belts and poor urban air quality. In addition, due to economic globalization and foreign trade, there is a high demand for economic development, which inevitably leads to enormous energy consumption and carbon emissions. These actions have resulted in severe environmental pollution and degradation, which have brought detrimental effects to the world. Therefore, there is an urge for citizens to alert environment protection. According to the UN Sustainable Development Goals (SDGs) Point 13 'Climate Action', it points out that global warming will predictably cause numerous natural disaster risks, such as smog, acid rain and melting glaciers (The Global Goals, 2023a). As a result, failure to act will have irreversible consequences and will not be conducive to sustainable development. Additionally, the point 15 'Life on Land' in SDGs states that dramatic loss of forests affects biodiversity and climate change, which also affects human livelihoods (The Global Goals, 2023b). Hence, public attention is important when it comes to human quality of life.

In recent years, organizations are actively formulating countermeasures to build an ideal green future. For instance, the Chinese government's white paper "China's Policies and Actions on Climate Change," published in October 2021, proposes new development concepts to develop the economy without damaging the ecological environment (Xinhuanet, 2021). It also actively advocates citizens to develop a green and low-carbon lifestyle and carry out activities such as 'National Energy Conservation Publicity Week', 'National Low-Carbon Day', and 'World Environment Day', where these activities actively popularize sustainability education to the public (Sample Database, 2023) Furthermore, the Hong Kong government issued the first "Hong Kong Clean Air Blueprint" in March 2013 and proposed a comprehensive vehicle emission control strategy to improve roadside air pollution (Environmental Protection Department, 2023). In the European and American countries, the National Environmental Policy Law was proposed in 1969 to encourage harmonious development between people and the environment (Energy.gov, 2023).

This paper will investigate the effects of engaging gamification in sustainability education with Augmented Reality (AR) game application and evaluate whether the methods can awaken public awareness on environmental protection and promote a low-carbon green lifestyle from learning.

2. Problems

2.1 Lack of Student Engagement in Low-Carbon Living

According to a survey conducted by Professor Kenneth Wong and Mr. Alan Tse at Hong Kong Baptist University in 2013 ("Knowledge Development," The Hong Kong Baptist University, 2013), secondary school students in Hong Kong are concerned about the impact of climate change, but are not sufficiently engaged in low-carbon living. This indicates that low-carbon living is not yet a familiar concept in society. Furthermore, the interviewed students demonstrated weak knowledge of environmental protection and lacked engagement in sustainable activities. These results suggest that although Hong Kong students are educated about the consequences of not being green, they lack the knowledge and passion to act green. As teenagers are the main target group for education on sustainable living, there is a need to increase their awareness and engagement.

2.2 Inelasticity of Daily Habits

Achieving low-carbon living requires significant changes in lifestyle and consumption habits, which is challenging for many people. According to Hong Kong's Climate Action Blueprint 2050 (Climateready.gov.hk, 2023), citizens are encouraged to change their daily habits, such as using public transportation and minimizing unnecessary purchases, to reduce carbon emissions. However, changing habits requires persistence and can be difficult for many people in the long run.

2.3 Deficient Sustainability Education

Professional education and research data indicate that environmental protection education should begin with children to cultivate low-carbon energy-saving awareness from an early age and establish a social consensus (City University of Hong Kong, 2018). However, even though many online resources and physical talks are available for the public, parents may not enrol their children in these programs due to concerns about their academic performance. As a result, children may miss the opportunity to absorb essential knowledge about sustainability education during their early years, leading to a lack of understanding and concern for environmental protection.

2.4 Lack of Standards and Guidance in Carbon Neutrality

In many countries, governments and companies do not establish policies or measures to reduce carbon emissions (UNEP and UNEP Copenhagen Climate Centre (UNEP-CCC), 2020). They often prioritize economic development over the importance of carbon neutrality. Some governments may refer to countries such as France as examples for reducing carbon footprints (Touratier-Muller, Machat & Jaussaud, 2019).

2.5 Short Summary

Carbon neutrality is a global environmental goal that requires more efforts to be achieved. Education and training are necessary, especially among students, to raise awareness and understanding of environmental protection. To address this, we propose designing an educational environmental protection game to teach basic knowledge and skills, such as reducing carbon emissions, energy conservation, waste sorting, and resource recycling. Through an interactive approach, the game can promote environmental awareness and behaviour, encouraging students to become more conscious, responsible, and creative individuals. Our innovative approach aims to intrigue students' interest in sustainability and promote a green lifestyle in the long run, contributing to achieving carbon neutrality and environmental goals.

3. Literature Review

3.1 Learning from Carbon-Carbon Island

'Carbon-Carbon Island' is a mobile game designed to educate people about environmental problems, specifically carbon neutrality. The game uses simulation and educational game design to make environmental protection issues more accessible and understandable to users. It simulates different scenarios to attract players' attention, allowing them to gain a better understanding of the impact of human activities on nature. The game is mainly designed to be educational and aims to provide young people with sustainability knowledge in an engaging and interactive approach. It also encourages players to continue learning about environmental protection by earning

points to buy different digital plants in the game. Overall, 'Carbon-Carbon Island' is a creative and effective approach to educate and inspire people to act on environmental protection.

Figure 1: Screenshots from Carbon-Carbon Island

Figure 2: Screenshots from Ant Forest

3.2 Learning from Ant Forest

Ant Forest is a mobile application developed by Alipay, an affiliate of Alibaba Group. It is designed to motivate and encourage users to reduce their carbon footprints. It uses gamification to make the experience engaging and fun (United Nations Climate Change, 2019).

One of the main features is its realistic simulation. Users can plant virtual trees in the app's digital forest by accumulating energy through various activities, such as walking, cycling, and taking public transport. The app tracks user activities and converts them into ‘green energy’, which can be used to plant virtual trees. As the app users reduce their carbon footprints, the app allows them to plant more trees and grow their virtual forest. Also, the app provides educational information on different tree species, marine life, and other environmental concepts. This attempt aims to inspire app users to care more about the environment and understand the impact of their actions on the environment. Certificates will be given to users who participate with a certain amount of game time, making the experience more enjoyable by sharing their achievements on social media.

Another unique feature of Ant Forest is its real-world impact. As users accumulate energy and plant virtual trees, the company will represent users to plant real trees in desert areas. Actions in virtual world can be transferred to reality and it is much more meaningful and impactful to sustainability.

In conclusion, Ant Forest is an innovative and effective way to encourage individuals to reduce their carbon footprints by planting virtual trees. Not only playing a mobile game, but players can also actually contribute to real-life environmental protection, and it would be much significant to protect environment while enjoying the game.

3.3 Online Games for Sustainability Education

Learning by gamification has been promoted in years that some experiments proved that it can raise effectiveness on learning a specific concept or knowledge. A case study held in Taiwan tested students’ environmental knowledge in an online gaming competition (Da Ai Television, 2022). Students were found to be enthusiastic and motivated by the awards, and they were evaluated by teachers with environment-related questions. The results showed that students can learn more effectively when games are included.

3.4 Benefits of Cartoon Design in Attracting Teenagers

Cartoons and comics have traditionally been perceived as sources of entertainment rather than educational tools. However, recent studies have indicated that they can effectively communicate abstract knowledge in a tangible form that is easily comprehensible to young people (Osborne, 2019).

Teenagers are increasingly drawn to cartoon-based media, such as Japanese animation and video games. Cartoon characters possess qualities that appeal to teenagers, including appearance, personality, and actions (Cooper-Chen, 2010). If designed with appropriate features, these characters can leave a deeper impression on teenagers, prompting further reflection and enhancing their understanding of the knowledge presented.

In educational application design, attractiveness is vital. Traditional learning methods can be boring, but cartoons can create a more relaxed atmosphere that feels more like 'playing' than 'learning', providing more space for recipients to engage with the materials (Kalboussi, Mazhoud and Kacem, 2016). This approach can be particularly effective for teenagers, who may have shorter attention spans and be more easily distracted.

In short, cartoons and comics are exceptional educational tools that can help convey abstract knowledge in a more tangible form that is easily understood by young people. By designing cartoon characters with suitable features, educational context can be more attractive and engaging for teenagers. In educational application design, creating a relaxing atmosphere using cartoons can be an applicable technique to promote learning and retention of information.

Figure 3: Cartoon UI design

3.5 Green Tech

Green Tech is a new concept that encompasses technologies which are environmentally friendly (Ishak, Jamaludin and Abu, 2017). With the world facing serious environmental problems due to human activities, the importance of green tech is becoming increasingly apparent. Green technologies offer many benefits, including reducing energy and water consumption, lowering waste production, decreasing our carbon footprint, and increasing business efficiency by reducing costs, improving product design, and creating new jobs (Iravani, Akbari and Zohoori, 2017).

One advantage of green technology is the reduction of waste and improvement of recycling. By implementing green technology, companies can decrease the amount of waste they generate and mount the use of recycled materials (Haleem et al., 2023). This helps conserve natural resources and reduce the amount of waste that ends up in landfills and oceans.

Green technologies can enhance technology-related efficiency and lower business expenses by reducing energy and water consumption, helping to promote sustainability in the business world. Additionally, green technologies can help reduce social issues, power consumption, and create more employment opportunities. Overall, Green Tech is an essential concept for entrepreneurs and the direction for technological development to create a more sustainable future for ourselves and future generations.

4. Research Methodology

4.1 In-depth Interviews (IDI) and Focus Group (FG)

A total of 4 IDIs and 1FG were conducted on 10-13 May 2023. Each IDI and FGI lasted for 1 hour and 2 hours respectively.

Table 1: In-Depth interview and focus group

	ID1	**IDI2**	**IDI3**	**IDI4**	**FG**
Respondent profile	S4, Male Liberal & Business subjects English-medium class HK Island school	S4, Female Liberal & Science subjects Chinese-medium class Kowloon school	S5, Male Liberal & Business subjects English-medium class HK Island school	S6, Male Science & Business subjects Chinese-medium class	Secondary school teachers, 3 F & 2M 3 teaching English-medium class and 2 teaching

	ID1	IDI2	IDI3	IDI4	FG
				Kowloon school	Chinese-medium class
Students: All have experience in developing good environmental habits. **Teachers: All have experience in environmental conservation work**					

4.2 Define

4.2.1 Identify subtle reminders as key to environmental protection

According to the interviewed students, developing good environmental habits is an ongoing process that requires subtle and continuous reminders. They suggest starting with small but meaningful actions, such as reducing waste and using reusable bags and water bottles. The students emphasize the importance of raising awareness and promoting environmental education in schools, communities, and families to foster a culture of sustainability and responsibility.

4.2.2 Advocate software or game for environmental education

The interviewed teachers suggest that using software or games can be an effective approach to promote environmental protection and cultivate good environmental habits among students. They believe that electronic forms can make learning about environmental issues more engaging, interactive, and accessible, and can also help students develop digital literacy skills. The teachers emphasize the importance of developing electronic materials that are age-appropriate, culturally relevant, and aligned with the curriculum. The teachers also suggest that software or games can encourage students to adopt and sustain good environmental practices, such as reducing waste, conserving energy, and using sustainable transportation.

4.2.3 Identify game themes for environmental education

The interviewed teachers express that environmental education games and apps with themes such as tree planting, climate change, renewable energy, food carbon footprint, and daily carbon reduction behaviors are highly relevant for cultivating good environmental habits among students. They find that these games offer diverse gameplay and innovative interactive forms, such as gamification, drag-and-drop, and gesture recognition, which can keep students engaged and motivated, enhancing their learning outcomes. The teachers believe that gamification can be used to encourage students to turn environmental protection into practical action and make our world a better place.

4.3 Prototype

This game design provides users with a variety of environmental games to experience and learn about environmental conservation. The games are designed to be both entertaining and educational, allowing users to engage with environmental issues in an interactive and immersive way. Through games, users can learn about topics such as renewable energy, waste reduction, and sustainable living. This game design aims to raise awareness and encourage positive environmental action in public.

Figure 4: Game menu

4.3.1 AR/VR green deck

This feature introduces users to the benefits of tree planting, including reduced air pollution, energy conservation, improved water quality, and enhanced wildlife habitats. In the context of Hong Kong's Hung Hom Submarine Tunnel, tree planting can help alleviate air pollution in a particularly problematic area. Through virtual and augmented reality, students can learn about the importance of green tree planting and become more

engaged in environmental conservation. By increasing awareness and understanding of environmental issues, we can work towards a more sustainable future.

Table 2: Game theme design graph

Figure 5: Screenshots for AR/VR Green Deck

4.3.2 Game 1 – The Challenging Climate in Hong Kong Sort In Out

This feature requires users to understand dangers and opportunities facing in Hong Kong's climate. Through interactive question-and-answer mini-games, students can gain a better understanding of Hong Kong's climate.

The rules of the game are as follows:

- There is a time limit of 1 minute.
- The user must select the correct answer. If the answer is correct, points will be added to the account, and points will be deducted for incorrect answers.
- Failing to answer three questions correctly will result in failure.

Overall, this feature is designed to help users better understand the challenges and opportunities facing Hong Kong's climate. By interacting with mini-games, students can learn in a fun and engaging way, while also gaining valuable knowledge about environmental issues.

4.3.3 Game 2 – Every Step Counts

This feature allows users to learn common environmental protection techniques, such as using cloth bags for shopping, avoiding waste, and other behaviors. By answering questions, users can increase their awareness of daily life environmental protection expertise.

The rules of the game are as follows:

- The system generates questions with different options for everyday life-saving tips.
- Users receive reminders and learn more about environmental protection knowledge when they select correct or incorrect answers.

This feature is designed to help users learn practical environmental protection expertise that can be applied in their daily lives. By answering questions and receiving feedback, users can increase their awareness of environmental issues and develop sustainable habits. By promoting environmental protection knowledge in a

fun and attractive conduct, this feature can inspire positive changes and encourage users to keep their habits in sustainable lifestyles.

Figure 6: Screenshots from Game 1 – The Challenging Climate in HK Sort In Out

Figure 7: Screenshots from Game 2 – Every Step Counts

4.3.4 Game 3 – Understand Fuel Types

This feature allows users to learn about renewable and non-renewable energy sources, understand the reliability of different fuels, and increase environmental awareness.

The game rules are as follows:

- The system generates different fuels, such as coal, natural gas, and oil.
- Users choose different fuels and judge their reliability instantly.
- Correct answers earn points, while incorrect answers result in failure.

This feature is designed to help users understand the reliability of different energy sources and promote a better understanding of environmental issues. By learning about renewable and non-renewable energy sources, users can consider more choices on their energy consumption and reduce their personal impact on the environment.

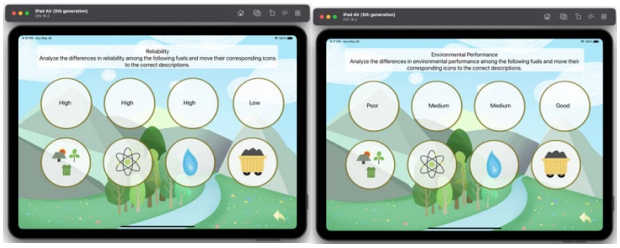

Figure 8: Screenshots from Game 3 – Understand Fuel Types

4.3.5 Achievements design

In this feature, users can exchange rewards for different roles using points and share them on various social media platforms. Users can earn tokens by winning games and exchange medals with the tokens. Those medals can be shared on social media platforms for sharing.

This feature is designed to incentivize users to engage with the app and promote sustainable behaviours. By earning points and exchanging them for medals, users can feel a sense of accomplishment and be motivated to continue using the app. By sharing their achievements on social media platforms, users can also inspire others to make positive changes in their own lives.

Table 2: Achievements design

No waste	Save electricity	Eco-friendly travel
Eco Bag	Water resource	Love the earth
Caring environment		

4.3.6 AI Hand landmarks Design

Hand gesture interfaces are becoming increasingly popular as a method of interacting with digital devices. These interfaces provide the advantage of convenience, allowing users to communicate with devices in the most natural way possible. This technology has shown great potential in human-machine interaction and is becoming more prevalent in games and other applications (Ertugrul, Li and Sheng, 2020).

One of the key advantages of hand gesture interfaces is their flexibility and richness. These interfaces allow for a wide range of gestures to be used, providing users with a more intuitive and engaging experience. This can be especially beneficial in games, where precise and efficient targeting can be crucial for success. By applying AI landmarks, players can easily control the cursor and use it to efficiently target specific objects. This helps to enhance the user's experience and make the game more promising.

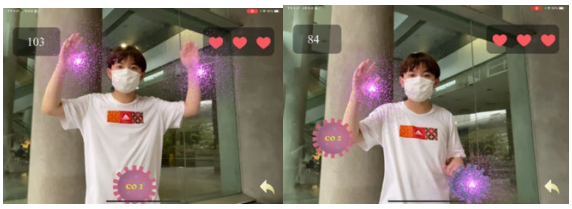

Figure 9: Demonstration on AR interactive game

4.4 Evaluation

The evaluation of the environmental education game showed promising results. A total of 130 students were invited to experience the game by downloading it. Pre- and post-surveys were conducted to evaluate their environmental knowledge. The results showed a significant increase in the students' overall scores on the post-survey compared to their pre-survey scores after playing the game. Specifically, there was a notable improvement in their understanding of topics related to renewable energy, waste reduction, and sustainable living. Furthermore, the students reported a higher level of interest and motivation in learning about environmental issues after playing the game. The game's interactive and engaging features, such as its gamification elements and user-friendly interface, were positively received by the students. These findings suggest that the game was effective in promoting environmental education, increasing students' knowledge of environmental issues, and fostering their interest and motivation in learning about environmental sustainability. In summary, this initiative demonstrated the potential of using games as a tool for environmental education and emphasized the importance of engaging and accessible approaches in promoting environmental awareness among young generations.

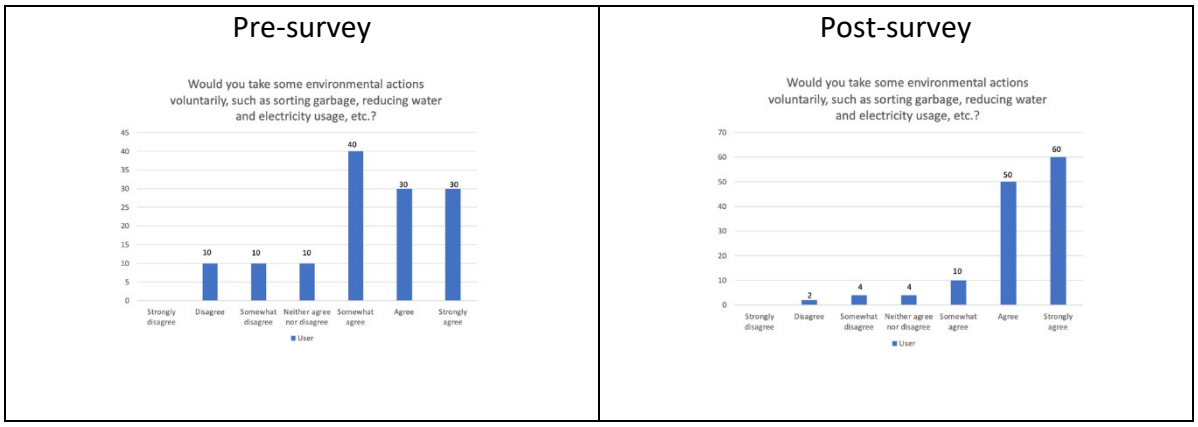

Figure 10: Bar graphs for pre- and post surveys on willingness to act green

5. Conclusion

5.1 Limitation

One limitation is that the app's game themes may require regular updates to stay current with users' preferences and interests, particularly for younger users. Another potential limitation could be the technology limitations of the user's device, such as processing power or storage capacity, which may affect the app's performance and functionality. It is important to consider these limitations when designing the app and to ensure that it remains accessible and engaging for all users.

5.2 Summary

The completed game advocates for environmental protection and encourages environmentally friendly behaviors to address the world's pressing environmental issues. Through the game, players can adopt low-carbon lifestyle habits, promoting ecological balance and environmental health. The game also provides information about the benefits of environmental protection and the importance of daily environmental habits. The game design is accessible and easy to use, inspiring a new generation of environmentally conscious individuals committed to protecting our planet.

5.3 Recommendation

To attract users and enhance the learning experience, we could consider incorporating elements of the metaverse or popular gamification strategies that appeal to younger audiences. This could help create a more engaging and immersive experience for users, while also promoting environmental education and awareness.

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Guidelines for Playful Learning Design in VR/AR: Insights From Student Productions

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Abstract: The paper presents three perspectives on virtual reality (VR) and augmented reality (AR) as educational technology: one on the learning attributes of VR and AR, the second on practical issues and problems, and the third on learning design guidelines. The perspectives are explained through text, tables, and examples from engineering students' productions. The paper will be of interest to students, designers, and researchers of VR and AR for training and learning.

Keywords: Virtual reality, Augmented reality, Learning design, Playful design, Game-based learning, Educational technology

1. Introduction

VR and AR are collectively referred to as XR. The paper introduces three perspectives on XR as educational technology: one about the learning attributes of XR, the second about practical issues/problems, and the third about learning design guidelines and recommendations. The perspectives are explained in text and tables, and they are also illustrated by examples from students' productions.

Regarding the technology, AR and VR blend the physical and virtual environments (Klopfer 2008; Kerawalla 2006; Cheng & Tsai 2013; Dunleavy 2014). In VR, the user typically wears a head-mounted display that provides a virtual 3D world experience. AR overlays a virtual layer on top of the physical environment, with the most popular example being PokemonGo.

The student productions were from the fourth semester 15 ECTS course, Learning Technology 2, from the software engineering program titled Bachelor's in Game Development and Learning Technology. The course aimed to teach academic learning theory, motivational theory, and applied programming for external devices such as VR headsets and smartphones. The students were expected to apply their prior knowledge in 3D game engine programming, sensor technology, and game design to create these prototypes. The student productions are from the spring semesters of 2022 and 2023.

The students conceptualized a range of themes for their projects, including health promotion, first aid training, civil firefighting, diver training, and more. The goal of the prototypes was to provide engaging and interactive training experiences that would be more effective than traditional training methods. The prototypes were developed using Unity, a popular game engine, and tested on the Oculus Quest 1, a standalone VR headset. The development process was iterative, with the students receiving feedback and making improvements along the way. Formative evaluations were conducted in class four times to ensure that the prototypes were meeting the learning goals and objectives of the course. Additionally, some of the groups had expert consultants who provided domain knowledge and feedback.

Our approach to learning and teaching is grounded in social constructivism, which focuses on the collaborative nature of development. Vygotsky (1978; in Cooper et al. 2021) is famous for defining the zone of proximal development (ZPD) as the difference between actual development, as determined by a learner's independent problem solving, and potential development, as determined by problem-solving under adult guidance. In his view, guided activity done in the ZPD was the essence of teaching and learning. We expand the adult's role in the ZPD to include a teacher and educational technology perspective. Vygotsky himself also expands the concept to include play, games, and peers. In summary, teachers, play, games, educational technology, and peers can all bring the learner into the ZPD. The designer's challenge is to guide this process and guide the student into her personal ZPD while using the system. Below is a figure of the ZPD.

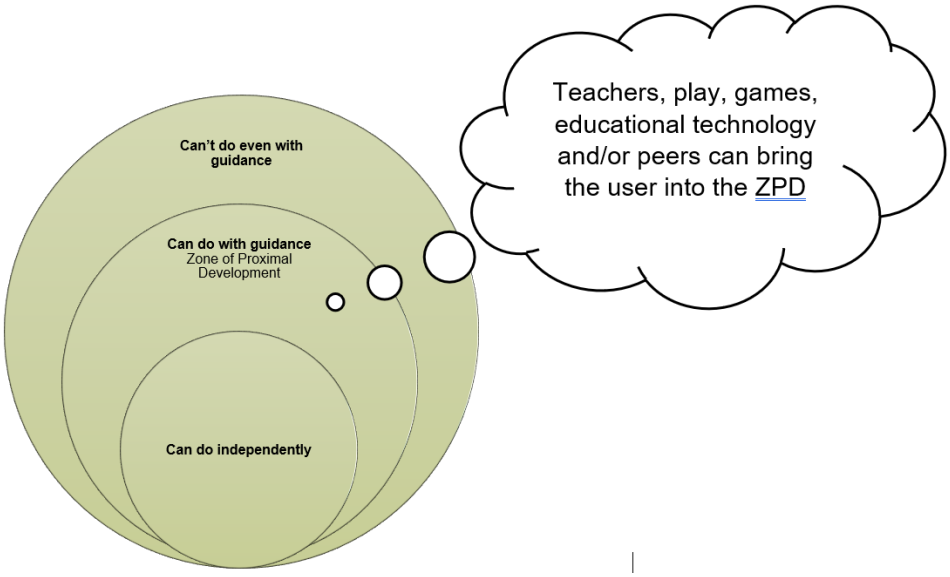

Figure 1: Teachers, peers, play, games, and educational technology can all facilitate the user's entry into the Zone of Proximal Development (ZPD)

In game-based learning, and educational technology, the idea is to alleviate and support the teacher by developing assistive digital applications (Cooper et al. 2021). The goal for the designer is to shape the system to support the ZPD, which can be achieved in various ways that will be discussed in the coming sections.

Organization of the paper: The paper is divided into three core sections that discuss the three perspectives on XR as educational technology: learning attributes of XR, practical issues and problems, and learning design guidelines, see the figure below. These sections are followed by illustrative examples from the students' productions. Finally, a summary of the paper is presented.

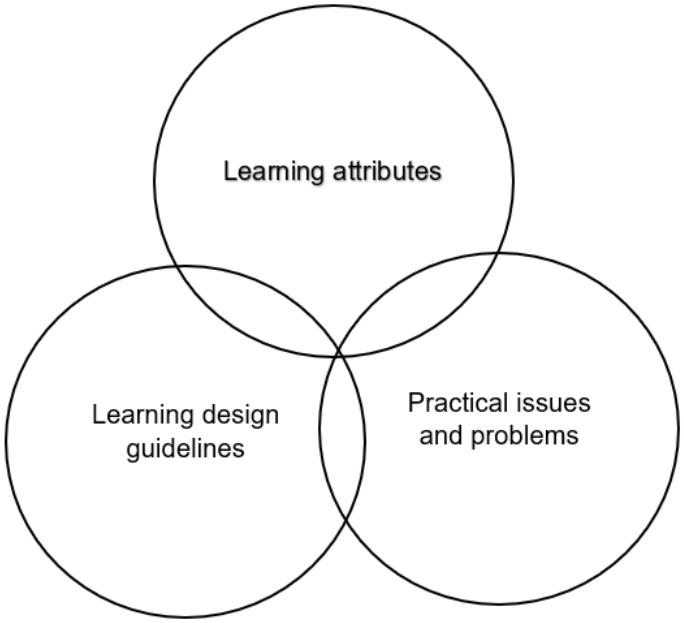

Figure 2: Three perspectives on designing educational technology for XR

2. Overview of Learning Attributes of XR

A lot of the potentials and challenges are similar in VR and AR as educational tools, so in this paper, we will assume similar affordances. XR are rapidly developing technologies that are being increasingly used in educational settings.

Immersion in the learning process is the most well-known argument for applying VR in teaching, training or psychiatric therapy (in the table 1 below). The intense feeling of being there, even though it's a simulation, has been noted by several studies (Calleja 2007; Kerawalla et al. 2006; Majgaard et al. 2017; Murray 1997; Waterworth 2014; McGonigal 2011). The environment can provide a *safe* real-life simulation without real-life consequences, for example, jumping off a roof in VR without sustaining injuries. Another compelling argument for the use of VR is its ability to create convincing simulations of real-life scenarios. Simulation and play have several overlapping characteristics such as context markers framing the scenario, actions without real-life consequences and make believe (Bateson 2000). Play and game characteristics in a simulation might engage the learner. An example of context markers could be a defibrillator, stretcher, band aid, people in white clothes in a first aid scenario in a simulated hospital. The learner will immediately understand what this is all about. The designer should introduce simple and understandable context markers to frame the scenario and engage the learner. *Playful learning* applies inspiration from the world of computer games.

Learning often takes place when the learner is actively participating and exploring the subject matter. The learner interacts, reflects, and forms experiences this is ascribed as *experiential learning* (Kolb 1984; Kolb et al. 2011; Majgaard et al. 2020). The learning environment should be designed to be interactive to support experiential learning and *interactive learning* processes. It should be noted that interactions should be meaningful and closely related to the subject matter (Gee 2004). Repetitive, meaningless, interactive micromanagement will not support the learning process; on the contrary, it will bore the learner. Designing educational tools is a delicate balance between repeating what the learner already knows and gradually introducing new challenges. *Practice learning* is supported by simulations of complex real-life situations, for example, providing first aid in the middle of a crowd. The simulations could also support the practice of, for example, the order of lifesaving procedures or other medical procedures in VR or AR.

XR allow for personalized learning processes. The learner can train at their own pace and repeat the subject matter as many times as needed without the system losing patience. The system can be tailored to *individual learning* styles (Gee 2004). The learning process is often individual and solitary. *Social learning* elements in XR are in their infancy, but soon, we will explore social spaces where learners can discuss and interact meaningfully[1]. XR technology can make learning *accessible* to learners with disabilities who might otherwise struggle with traditional teaching methods.

Learners in XR are often unfamiliar with the interaction method. In most VR applications, the controllers are invisible while wearing the headset. Therefore, the designer often needs to start with a tutorial scene to teach the use of the controllers. Often, the designers provide visual guidance because text is considered clumsier from an affordance perspective and long text sections are also difficult to read in VR (Norman 2002).

XR technology can effectively *visualize 3D* models and add a new dimension to the physical surroundings, such as revealing hidden clues or information on real-life maps or details in the solar system that cannot be seen with the naked eye. This attribute can be described as seen the unseen (Dunleavy 2014; Majgaard et al. 2017; Nørgaard et al. 2019; Mantovani 2003; Martín-Gutiérrez 2010).

Below are some potential benefits and challenges of XR technology for learning. The table is divided into attributes, with the potential benefits and challenges outlined for each. While the table covers a comprehensive set of aspects, it is not exhaustive, and additional themes/attributes could be considered.

Table 1: Overview of learning attributes and their potentials and challenges in VR/AR

	Attributes	Potentials and challenges
	Immersive Learning.	Potential XR technology provide an immersive learning experience that engages students in a way that traditional teaching methods cannot. Potential: Students with attention issues can easier concentrate in VR because of the limited number of distractions Challenge: The immersive nature of AR technology can

[1] Social networking https://allvirtualreality.com/review/best-social-networking-apps-vr-oculus-quest.html

	Attributes	Potentials and challenges
		be distracting and may interfere with learning, especially for students with attention issues.
2	Playful learning	Engaging learning environment inspired by the world of computer games
3	Safe Learning Environment	Potential: XR technology provide a safe learning environment where students can explore and experiment without the risk of real-world consequences.
4	*Experiential learning*	Potential: Provide the learner with new activities and experiences that encourage reflection and foster learning
5	*Interactive learning: Learning by active participation*	Potential: interacting centered around academic learning goals Potential: XR technology allow for interactive learning experiences that facilitate active participation and feedback. Potential: Actions instead of text and words Challenge: Reading and writing in VR
6	Practice learning: Simulations in real-life context	Potential: AR and VR can provide surroundings which emulate complex real-life situations. Potential: Learning new practices by training in VR simulations
7	Individual Learning processes	Potential: XR technology allow for individual and personalized learning experiences that can be tailored to each student's needs and learning style.
8	Social Learning processes	Potential: In the future we might sed more social spaces where user can meet in VR/AR and learn together Challenge: XR technology can be isolating and may not provide the same level of social interaction as traditional learning methods.
9	Accessible Learning	Potential: XR technology can make learning accessible to students with disabilities, who might otherwise struggle with traditional teaching methods.
10	Learning by imitation or practice learning	Potential: The learner imitates steps in a complex procedure for example steps in an epidural procedure in a health context.
11	Visualizing and/or coupling of 2D and 3D objects	Potential: Visualizing and inspecting 3D objects from all sides Potential: Coupling of 2D and 3D models are often difficult in book but easier in XR
12	Seeing the unseen	The technology can add a lens to the physical surrounding e.g. see hidden clues or written information on real-life objects

3. Overview of Practical Issues Using XR

The XR interfaces are in their infancy. There are not a lot of applications, the development of new applications is expensive, new versions of headsets are surfacing every year, and the headsets are expensive in a school setting. In combination with smartphones, the technology is more accessible (Issue 1 and 3, see the table below).

Motion sickness is a well-known phenomenon in VR because there might be a small delay or difference between head movements and movements seen in the headset (Issue 2). Motion sickness happens when the movement you see is different from what your inner ear senses. The sensitivity to motion sickness differs from person to person. Designers use all kinds of tricks to minimize the sickness, for example, providing a windshield frame when simulating driving cars or flights. Another trick could be to minimize multiple objects in the

periphery of the eyes (LaViola 2000). Too much immersion can also cause dangerous situation where users fall or run into walls (Issue 4).

Table 2: Practical issues using XR

	Issue	Potentials and/or challenges
1	Cost-effective?	Potential: XR technology can be more cost-effective than traditional learning methods, especially for hands-on, experiential learning. Challenge: The availability of educational XR content is limited, and creating high-quality content can be time-consuming and expensive.
2	Cyber sickness - motion sickness	Challenge: XR technology can be disorienting, and in some cases, can cause motion sickness, which can be a safety concern. Prevention: The designer can design to reduce the potential cyber sickness e.g. by reducing mismatch between user movements in the simulation and the physical environment
3	Technical Issues and immature technology	Challenge: XR technology require high-performance hardware and software, which can be costly and difficult to set up and maintain.
4	Immersion issues	Challenge: Users might also fall or run into wall, so beginners should be watched.

4. Overview of Playful Learning Design Guidelines of XR

Learning design involves planning, facilitating, and conducting teaching, in this case, involving educational technology. It focuses on the activities that learners need to undertake to achieve the learning goals (Weitze 2015). How is learning design activities designed into XR applications? And how is the learner guided to reach the learning goals? When using digital technology in education, there will be two types of didactic learning designs: the automated and the teacher-led teaching activities. The teacher-led activities take place before and after the use of digital technology. Before XR, there will typically be an introduction to the academic field and the digital application. Then, students will work with the application, and finally, there will be an academic debriefing (Majgaard 2020). This means that in the design of learning technology, both an automated guidance for use in the system and a concrete proposal for how the technology can be incorporated into teaching must be developed, see the figure below.

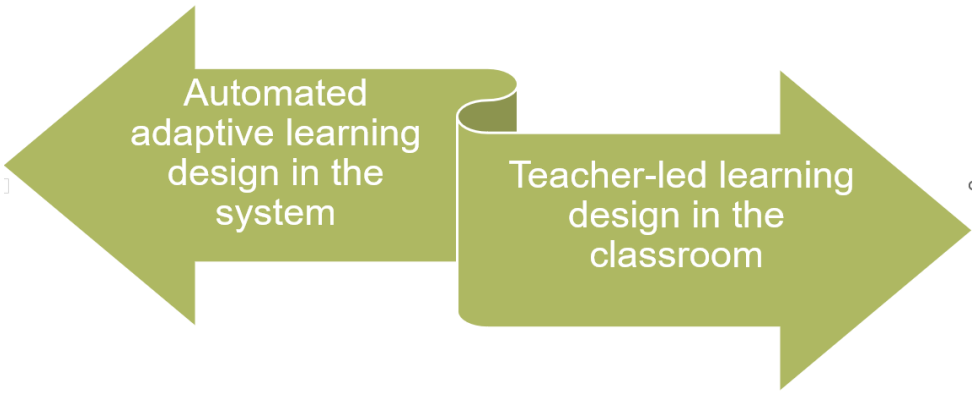

Figure 3: Overview of the learning designs: The automated built in learning design and the teacher-led learning design

In the table three we provide an overview of well-known playful learning design guidelines inspired by Gee (2004), Fan (2012), Habgood (2007) and Dunleavy (2014). The table covers ideas for the built in adaptive

automated learning design. The learning design elements should provide the learner with user guidance without introducing heavy tutorials (Fan 2012; Curtis 2012; and Majgaard 2015).

Fan (2012) the creator of "Plant vs zombies" outlined several tips for making tutorials more effective and smoother (Curtis 2012; Majgaard 2015). According to Fan there should be no tutorial page, the tutorial is seamlessly blended into the playful application. The learner doesn't have to read about specific actions. The learner is to be lured into doing a specific action just once. "Once they see the results of their action, that's often all it takes for them to understand that action," Fan said (Curtis 2012). Furthermore, the use of text messages should be minimised. The messaging should be adaptive and if the learner understands the mechanics no messages or arrows are displayed. The designer should prefer to use visuals to teach, e.g. an arrow, or just showing how interactive objects work. Too much information creates noise, e.g. messaging on things the learner already knows. See more in theme 3, 4, 5, 6 in the table below.

Gee (2004) provides a long list of elements from the world of computer games which can be applied in educational technology. In the table below we chose the elements from problem solving which are the most applicable for designers of XR. See more in guideline 2, 8-12 in the table below.

When the learner has become familiar with the controllers, the designer can introduce the subject matter without inducing cognitive overload (Dunleavy 2014). See more in guideline 1 in the table below.

The core game mechanics are where user interactivity takes place (Fullerton 2019; Habgood 2007). In educational tools, the designer should integrate learning goals with the core mechanics (Habgood 2007). Habgood (2007) developed a division game where the core mechanics revolved around finding the correct divisor (guideline 14).

Table 3: Overview of playful learning design guidelines to implement in VR/AR

	Guidelines for designing playful learning experiences	**About the guidelines**
1	Cognitive overload for beginners – complex interaction	The user interface / controller is often difficult to use. XR technology require a significant learning curve, which can be a challenge for both students and teachers who are not familiar with the technology. The learner should exercise using the controllers before introducing hardcore academic learning activities.
2	Elements for guiding the learner	The learner might not know what to do in VR/AR and what the overall purpose is. Introduce the learner to the learning activity.
3	Blend in the tutorial	Spread out the teaching of the mechanics.
4	Better to have the learner do than read	The learner remembers better when an action is performed. Just get the learner to do it once.
5	Use visuals to teach	Hint the user with arrows, movements or simulate the wanted action.
6	Use fewer words	Use fewer words (max. 8) Use unobtrusive messaging if possible. Use adaptive messaging. If the user is familiar with the activity skip the message.
7	Framing and context markers	Context markers can ease the understanding of the scenario. In a classroom, context markers are the blackboard, tables and chairs arranged in school setting. Don't create noise by adding random objects.
8	Pleasantly frustrating activities	If the challenge is too hard or two simple the learner will become frustrated and leave the simulation too soon. The design should balance skills and challenges in the learning activity.

	Guidelines for designing playful learning experiences	About the guidelines
9	Well-ordered problem and challenges	The learner should have well sized problems – simple in the beginning and more complex later. Problems in the beginning should lead to more complex and harder problems later.
10	Cycles of expertise	The learners should practice and repeat skills until they are nearly automatic.
11	Information on demand or just in time	Information should be presented when it is useful in the simulation. Spread out the teaching of simulation mechanics.
12	Sandboxes	Potential: a place to experiment practice without restrictions.
13	Asymmetrical VR	One user in VR and another in front of a computer
14	Core mechanics and interaction should relate to the learning goals	The core of the user activity should relate closely to the learning goals. It should not be about playing irrelevant mini-games in the systems.

5. Illustrative Examples From Student

In the following we will introduce selected illustrative examples from student projects from spring 2022-2023. The students' projects will illustrate examples of learning approaches, practical issues and learning design approaches. The learning attributes mentioned in Table 1, the practical issues outlined in Table 2, and the learning design guidelines specified in Table 3 form the key components for consideration.

Fear of flying

The *Fear of Flying* application is a VR simulation of a flight that goes through the safety instructions given to passengers at the beginning of a flight route. The app aims to help individuals who experience mild fear of flying to become more knowledgeable and comfortable with flying. This is done though providing an immersive (attribute 1, see table 1) and safe environment (attribute 3) that enables users to learn about the safety instructions giving during a flight in an interactive (attribute 5) and experiential manner (attribute 4). Though interactive learning, the user can participate actively in the learning process, interacting with different objects and performing tasks to progress though the simulation (guideline 4: Better to have the learner do than read). The simulation is divided into sections, and the user is presented with one problem at a time (guideline 9: Well-ordered problem of challenges) to avoid cognitive overload. The application also highlights key elements of the safety instructions at specific times (guideline 5: Use visual to teach), aiding users in seeing the unseen (attribute 12) and framing and contextualizing the information. The group was particularly attentive to cybersickness (Table 2) as turbulence was simulated, which required taking away user viewpoint control by "shaking" the surroundings – just like in the real world.

Asymmetric Mathematics

The game *Asymmetric Mathematics* provides a good example of how social learning (guideline 7) can be achieved through asymmetric VR (guideline 13). The game is an immersive VR learning application (guideline 1) that introduces playful game-like elements (attribute 2) to math learning in high school. The game is played in co-op mode, where one student is immersed in a VR classroom environment, using a classic representation of classroom, to provide a clear understanding of the game's setting (guideline 15) while the other player sits in the same (physical) room. They are required to collaboratively solve a series of mathematical tasks, which are presented to the player in VR. The player(s) in the physical room are provided with a special calculator that is connected to the VR simulation, which functions as a means of communications and serves as a formal collection of responses. The player in VR can observe a "bomb", which exhibits the time, number of strikes, and enables the selections of the questions to be answered. The application encourages interactive learning (guideline 4) though active participation and takes cognitive overload for beginners (guideline 9) into account, as the users are provided with a guide, step by step as the game unfolds. To address the issue of cybersickness (Table 2) the players are seated, limiting their movement to only their head.

H.C. Adventures

H.C. Adventures is an interactive, location-based AR application aimed at enhancing children's (in first and second grade) comprehension and learning of fairytales by Hans Christian Andersen. By collection location-based data from the user, the app generates routes around the user's actual surroundings. The user will along the route encounter segments of fairytale narrated by a talking hat inspired by H.C. Andersen. In addition, the talking hat acts as a supportive guide for the children, providing step-by-step instructions as necessary (guideline 11) to mitigate the risk of cognitive overload (guideline 1 and 2). Additionally, the child can follow along and read the fairy tale in a 3D AR book.

The app uses game elements and playful learning (attribute 2) to motivate children to read more and spend more time outside by providing a treasure hunt-like storytelling experience. Learning occurs through active participations (attribute 5) in three types of AR challenges, including a "collecting" task (coins and other assets from the fairytale), a picture puzzle, and a location-based task, where the user has to choose the correct destination among three options to proceed to the next scene. Additionally, users are able to interact with characters from the fairytale, affording experiential learning (attribute 4).

Moreover, the application promotes social learning as children can engage in group play and learning.

Fire simulation

The developed fire simulation application exemplifies the attribute of a safe environment (attribute 3). The application simulates a burning building, where the user is required to perform smoke diving and locate a series of objects. The usage of the application requires two individuals, one who is immersed in the virtual burning building, acting as the smoke diver, and another outside of the virtual environment, guiding the smoke diver. The application utilizes asynchronous VR (guideline 13), which affords social learning (guideline 9).

The application was designed in collaboration with firefighters to simulate the experience of how firefighters work in the real world. Through the application, users are expected to gain an understanding of the firefighting profession. This is achieved through interactive learning (attribute 5), practice learning (attribute 6), and experiential learning (attribute 4), where the user gains a first-hand experience of acting as a firefighter and searching for a series of objects in a burning building. The group encountered technical issues and immature technology (issue 3), which resulted in having to streamline the 3D content in the application to avoid excessive resource consumption. To minimize the risk of cybersickness, a teleportation system was implemented to restrict movement within the virtual environment to occur synchronous with the user's body.

We are in space

The VR application *We are in space* takes middle school students (7th to 9th grade) on a spaceship journey through the solar system, providing a dynamic and interactive (attribute 5) experience of discovery and theory as a supplement to physics education, particularly focusing on the attribute Seeing the unseen (attribute 12).

The app enables users to travel to different planets, explore them, cut them open (attribute 4), as well as view various information about them.

The user is provided with various means of interacting with and manipulating their environment, including buttons and handles to change planets or the starry sky. Users are presented with different missions, guided by the spaceships navigation system, which introduces information step by step to avoid cognitive overload (guideline 1) and guides the user (guideline 2). Through this, the user gradually acquires relevant knowledge about the planets, when necessary to complete a given mission illustrating the Information on demand guideline (11).

6. Summery and Conclusion

In the article, we presented three approaches to the development of educational tools in XR. The three approaches were: one on the learning attributes of XR, the second on practical issues and problems, and the third on learning design guidelines. The tables are a work in progress. In the illustrative examples, we related selected student prototypes to elements in the tables. This puts flesh and blood on the concepts in the tables. And it also gives readers an idea of the variation in the students' products.

In the LT2 course in 2023, students were asked to relate the tables to their development of educational tools in AR or VR. The students have not yet submitted their projects and reports by the deadline of this article. They were particularly discussing learning design guidelines, such as pleasantly frustrating activities. In user tests

(especially on younger students), they received a lot of feedback on whether the learners understand the intentions of the prototypes and whether they could figure out what to do in the simulations. Additionally, there were discussions about cybersickness and how to avoid it, such as teleporting within the application.

Based on the illustrative examples provided, the three tables have demonstrated their practical utility in designing and developing XR learning experiences. For instance, the Fear of Flying project demonstrated the implementation of an immersive and safe learning environment (attribute 1 and 2) designed to facilitate learning about safety instructions through an experiential and interactive learning (attribute 4 and 5) approach. To enhance user guidance and user experience, challenges were presented one at a time (guideline 9) and visual effects such as highlighting of relevant objects (guideline 5) were employed.

In the Fire simulation project, a safe learning environment (attribute 2) was also created, allowing users to experience firsthand smoke diving through experiential learning (attribute 4).

The utilization of the social learning guideline (guideline 7) was effectively demonstrated in both the Asymmetric Mathematics project and the Fire simulation project, wherein asymmetric VR (guideline 13) was employed. Furthermore, the Asymmetric Mathematics exemplified the playful learning attribute (2) by integrating game-like elements. Similar utilization of game elements was observed in the AR project, H.C. Adventures, where the game elements were used to enhance children's motivation to read more.

The We are in space project particularly illustrates the attribute of seeing the unseen (attribute 12) and the guideline information on demand (guideline 11). In this simulation, users have the opportunity to explore planets up close, including the ability to split them in half to view their interiors. Additionally, the students in this project focused on introducing information in a step-by-step manner (guideline 1) and only providing information when necessary (guideline 11).

To conclude, the tables are an operational and practical step towards developing XR systems for learning and training. It is also clear that more evaluation is needed on the students' use of the tables.

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Sandwich Robot for Computational Thinking: Reflections From Testing With High School Pupils

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Abstract: Our study discusses results from testing and co-designing *Sandwich Robot*, a game on algorithmic thinking targeting beginner programmers. The player composes code from a minimal set of blocks, to make a robotic character gather ingredients for a sandwich, following a specific order; the gameplay is similar to other Computational Thinking (CT) games like *Karel the Robot* or *LightBot*. The latest prototype of the game has been tested with three classes of 15-20 pupils from a technical high school in Denmark. The test was conducted in collaboration with their teacher in the subject *Informatik*, which focuses on CT and basic programming, and ended with a co-design workshop. Our results shows that pupils were interest in the basic concept behind our game, they generally described our game as "fun". Pupils and their teacher saw learning potential in the game, as a tool for understanding algorithmic thinking, but also for refining their learning at later stages. This expanded the role we envisioned for our game, leading us to rethink its relation to the pupils' learning process. On-going and future work involves addressing pupils' feedback and providing a level editor to allow Kahoot-style challenges. Our main contribution provides an exemplar of how the thinking behind algorithmic problem-solving can be transposed into game mechanics, embodied in a casual game, and how a non-technical narrative can support beginners learning CT.

Keywords: Computational Thinking, Playful learning, Games, Co-design, High school

1. Introduction

This study proposes a User Centred investigation about how beginner programmers face algorithmic thinking in solving computational problems, in CT. We are interested in investigating which kind of solutions they would adopt, while dealing with the complexity of algorithmic thinking, and which factors can challenge beginners in formulating algorithmic solutions. We also want to look at how a CT casual puzzle-like game with a funny narrative, designed to demystify technical and mathematical aspects of CT, could foster algorithmic thinking practices through code manipulation. Sandwich Robot is conceptualized as a casual game, not to feel intimidating for non-hardcore players imposing them a high-paced, challenging gaming style. Casual games are in fact designed for a wide audience, not requiring high-level gaming skills or strong time commitment (Kultima, 2009). The game, *Sandwich Robot*, proposes one puzzle per level, where a player must instruct a robot to collect ingredients and make a sandwich; the game uses a Blockly-based visual language for the instructions, and has an occasional-style gameplay.

Our inquiry was conducted in close collaboration with a teacher of the subject *Informatik* at Oerestad Gymnasium (OEG) in Copenhagen. Informatik in Denmark is the main subject focusing on developing CT competences and basic programming skills at a high school level (see the official definition of the subject, in Danish: https://www.ug.dk/6til10klasse/informatik-paa-de-gymnasiale-uddannelser). Our user group is based in a technical high school, and the study program has great focus on scientific subjects, including coding and mathematics, therefore, we experienced that the pupils were generally motivated to engage in programming, some seemed passionate about it, while for others it was part of their daily learning activities. CT was generally framed within creative interventions, such as designing websites, games or apps for local institutions (Witfelt, 2022). In this sense, proposing a game for simplify algorithmic problem solving for the pupils fitted well the current pedagogical practices of the school, and the teacher saw our game as a meaningful resource to introduce specific aspects of CT.

In the next section we introduce the theoretical grounding of our study and related work, afterwards we present our methodology for data gathering and analysis, thus the design and implementation of Sandwich Robot are presented, and finally we analyze and discuss our gathered data.

2. Related Work – Theory and Existing Research

Our study is mainly grounded on CT and Hermeneutics (Gadamer, 1989), as a pedagogical framework to foster understanding of CT through digital games. Hermeneutics describes learning as a path along a *circle*, starting from learners' previous knowledge and acquiring new knowledge while proceeding across this circle and

encountering new texts to interpret (Gadamer, 1989; Sotirou, 1993). During this path, conflicts arise as these new texts might contradict the learners' previous knowledge; however, previous knowledge still provides a resource to deal with new directions for meaning making (Tomkins and Etough, 2018). In this context, we see casual games as hermeneutic resources to foster learning of algorithmic thinking within a familiar framing. Casual games are designed to address a wide audience, displaying different levels of skills and commitment to gaming, building on principles such as: *Acceptability,* as they do not include controversial topics and are often free to play; *Accessibility,* these games do not require extensive training to be played, being typically seen as a secondary activity, and are easy to find and install; *Simplicity,* game mechanics and functional elements are kept to a minimum, or automated, like saving (Kultima, 2009). Casual games are perceived as non-intimidating, which can easily fit other purposes like learning, physical or mental exercise or even providing relieve from stress and anxiety (Pine et al., 2020). In our game, the casual-style narrative of *instructing a robot to make a sandwich*, was chosen to frame programming within cooking, a simple daily activity and recurrent theme in casual games (Kultima, 2009), and the robot as a main character suggests a playful automation scenario.

CT has become a highly popular learning topic, following its popularization by Wing (2006, 2011) who stressed the importance for all citizens to develop a mindset corresponding to that of computer scientists and engineers. We follow a recent adaptation of Wing's definition, according to which CT *"consists in the cognitive processes involved in the development of digital artifacts and programs to live in today's world."* (Dohn et al., 2022). This definition on the one hand is useful in formulating as a main goal in the global society that more children and young adults become proficient makers of technological artefacts. On the other hand, it allows querying how appropriate any given digital artifact is for living in today's world, ethically, socially, environmentally (etc.) speaking. Thus, the definition speaks to other understandings of CT, which focus on fostering young people's awareness of the risks and rights of our information technology (Grønning, 2017). More generally, over the past decades, CT has developed into a complex umbrella concept for an interdisciplinary knowledge area, including hardcore technological skills, like coding or making digital artifacts with microcontrollers, as well as soft skills rooted on design and social sciences, related to conducting iterative design processes and understanding how technology use can affect individuals and groups (Tedre and Denning, 2016). Dohn et al. (2022) present a framework that explicates this umbrella concept, highlighting three basic approaches: a cognitive (focused on arithmetic thinking processes), a situated (focusing on pupils' participation in creative coding practices) and critical (focusing on critiquing ethical and political implications of algorithms in society).

In the Danish school system, in which we conduct our inquiry, many schools have adopted a hands-on learning approach to CT within existing subjects. Here, teachers and pupils engage in making high-fidelity prototypes, tinkering with sketches and digital technologies, developing both soft skills and some hardcore competences of CT. Still, according to our contact teacher from OEG, most pupils find challenging to understand algorithms and craft code in programming languages and, furthermore, they present different proficiency levels, making it harder for the teachers to address all the pupils' needs. Therefore, in our CT studies we address how to expand the available palette of learning tools and resources, to support teachers in framing these aspects of CT. In order to identify key areas for learning CT, we refer to Chongtay's (2022) taxonomy of CT skills:

- Decomposition – logical analysis and data organization.
- Pattern matching – representation of data through model and simulations.
- Design of algorithms – construction of automatic, sequence-based solutions.
- Pattern generalization and abstraction – generalization of algorithmic solutions from one specific problem to a class of similar problems.

Interestingly Chongtay's first two skills deal with analytical competences, such as being able to logically analyze data structures and representations in computational models. While the more advanced principles deal with active design of algorithms, creating an automatic solution to address a computational problem, and finally abstraction and generalization in designing algorithmic solutions that could address not only one but an entire class of computational problems. The last skill deals with structured use of programming languages, reusing code, and being aware of how control flows through their code depending on inputs.

3. Our study: Design and Data Collection

Sandwich Robot is a game on algorithmic thinking, targeting beginner programmers. The player composes code from a minimal set of blocks, to make a robotic character gather ingredients for a sandwich, following a

specific order. The gameplay is similar to other Computational Thinking (CT) games like **Karel the Robot** (https://compedu.stanford.edu/karel-reader/docs/python/en/intro.html) or **LightBot** (https://lightbot.com/).

Figure 1: Level 1 is visible on the left, with the GUI of the game; on the Right, a detail of the blocks

Figure 1 shows the whole GUI for level 1 of the game. The page has the typical layout of a block coding application: on the left the area where the blocks can be moved to compose code, a "run" button to execute the code, and on the right the world in which the execution will take place, in our case it is *map of the shop* with the robot and the ingredients. The "run" button is near a slider that controls the speed of the execution, and an "help" button. On top of the shop map there is the sandwich assembling area, where the ingredients collected by the robot will pile up. Finally, at the bottom of the shop map area, the goal shows which ingredients should go in the sandwich: here tomato, salad and ham, in that order. The far-right part of figure 1 shows all commands available in the minimal Blockly language that the robot understands: blocks for **moving** and **rotating**, **conditional** and two kinds of **loops**. We designed this language not to be Turing complete, and apart from the *untilStepOn* loop, all other commands always terminate in one or a small number of steps; this fact has a pedagogical consequence: it makes the **Notional Machine** (Sorva, 2013) very simple, while keeping the language in line with the core of any imperative programming language. The problem with the *untilStepOn* loop, is that it is fundamentally a *while loop*, i.e. if the condition is never met, the loop keeps running forever; we implemented infinite loop detection via step counting.

The latest version of the game is available at: http://www.andval.net/robot4/, it includes a practice level and ten levels, organized by growing complexity. Each of the ten levels can be solved by hard-coding all the steps and turns needed to build the correct sandwich; however, the game rewards solutions with 1, 2 or 3 *stars*, and a shorter, *smarter* code gives more stars. Moreover, we designed the level progression to help learners reflect on the various commands in our Blockly language: e.g. some levels have larger shop maps than others and few ingredients, and that is designed to make the *untilStepOn* instruction more relevant.

To better foster understanding of pattern generalization, our level design focused on grounding conditionals and showing that an algorithm is a solution to a class of similar problems. Hence, we devised *twin-worlds levels*, where the player writes a single solution to control two robots, simultaneously but each in its own separate shop map (Figure 4).

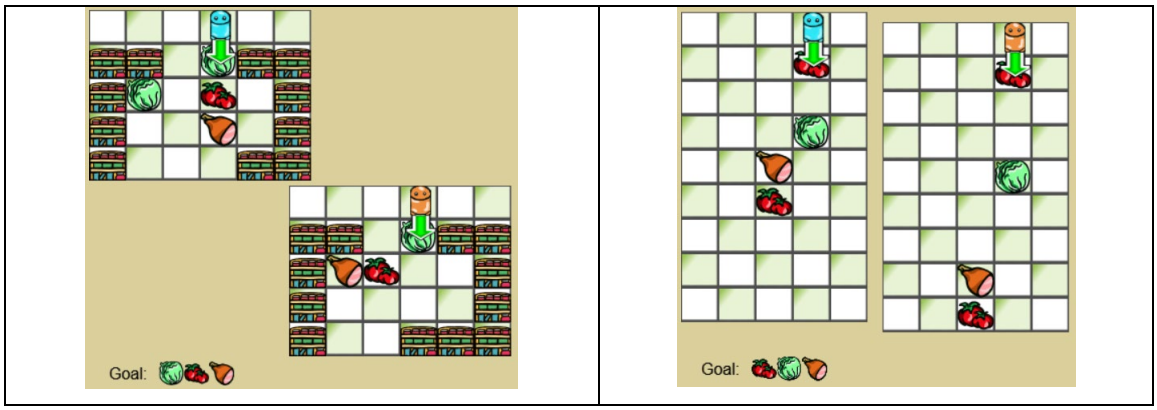

Figure 2: Twin levels 3 and 8 (left and right respectively)

Each level of our game can also be played offline, as a tangible version: the learners can print an A4 page with the shop map, cut the game pieces and play the game in class or at home. Supporting tangible interaction and offline continuation is central to our game concept (Marchetti et al, 2022).

The game is implemented as a serverless web application, using JavaScript and Google Blockly. When a new player starts the game, she is assigned a progressive number, and an entry is made in a mongoDB cloud database; all further attempts at solving a level (failed or successful) are sent to the database automatically, via AJAX, and stored in JSON format.

3.1 Ethnographic Data Collection

The empirical study builds on principles from User Centred Design (Preece et al., 2019), within a mixed method framework (Shannon-Baker, 2022), combining ethnographic observations, co-design and automatically saved data. Each of the pupils' gaming session was automatically saved, so that we could analyze how the pupils played our game, e.g. how many attempts to solve a level, if they played the levels in sequence or moved freely across, and which levels were most challenging.

We engaged in a close collaboration with a high school CT teacher and his pupils, so that we observed his learning activities (Marchetti et al., 2022), and then we involved his pupils in testing and improving our game. We are currently on the 2nd test iteration of our game and this time we tested with three different classes:

- 1st group – 14 pupils 9 boys and 5 girls in 3rd grade
- 2nd group – 17 pupils 13 boys and 4 girls 2nd grade
- 3rd group – 14 girls and 12 boys in 2nd grade

The length of high school in Denmark is three years, so the first group was at the final year of their education. The third group constituted the largest class we observed at the school. In general, all the classes were composed of males and females, from different ethnical background.

Our test was structured in 3 phases:

- Introduction and survey circa 30 minutes – the teacher presented us, our project and our game to his pupils.
- Testing Sandwich Robot 1 hour– the pupils play the 10 levels of our game under our supervision.
- Co-design session circa 2 hours – the pupils are invited to comment on post-its 3 positive and 3 negative aspects of our prototype, and to propose improvements to our game through collaborative sketching.

The teacher acted as our mediator, he was involved in planning the testing session, and provided a supportive presence, also securing correct communication given that two of us are not Danish native speakers. During our test, we gathered diversified kinds of data which enabled us to analyze the players' interaction with our game, both in terms of their performance and gaming experience. Table 1 shows an overview of the kinds of data that we gathered during the testing sessions:

Table 1: Type of data gathered during the test

Introduction	• Written Notes – response of pupils to our presence and test setup • Drawings – mood and bodily interactions among the pupils
Gaming Session	• Written Notes – from observations and informal situated interviews with the pupils • Drawings – Pupils' concentrated mood and bodily interaction while playing • Auto-saved data – automatic saving of each game session showing how the pupils played the different levels
Co-design Session	• Written Notes – from observations among the pupils as they were engaged in co-design • Drawings – showing how the pupils engaged with sketching during co-design • Sketches and notes – made by the pupils during co-design

To conduct an ethical data gathering, we agreed on our methodology with the teacher, who presented the whole procedure to the students and gave them the possibility to opt out of the study. To protect the privacy of the pupils participating in our study, we decided to avoid video recordings and instead we combined ethnographic observations with note taking and drawing. We see ethnographic drawing as a visual ethnographic tool, allowing to manually gather information, which might be complicated to described in words as ethnographers would do with a camera (Kuschnir, 2014; Marchetti, 2022), such as: facial expressions, bodily postures, gestures, and social interactions. A difficulty with ethnographic drawing is to capture dynamic actions, however, during our study the pupils were quiet and concentrated most of the time, except when they experienced the urge to communicate with each other, or with us: in such occurrences they would display changes in posture and facial expressions.

Finally, we collected sketches and notes created by the pupils during the co-design sessions. To facilitate the pupils to creatively tinker about our game, we provided sketching materials, such as: drawing paper, markers, scissors, tape, and printed handouts of the *twin levels* 3 and 8 of our games, which we see as most challenging (as discussed in the previous section). By providing templates of those levels, we hoped that the pupils could give us specific feedback on how to simplify them. This design material was acquired in the tool Nvivo and subject to a thematic cluster analysis, combining deductive and inductive coding (Shannon-Baker, 2022). Since we asked the pupils to list on sticky notes three aspects they liked and three they did not like about the game, we introduced a general deductive coding. On the other hand, the pupils' design proposals were analyzed inductively, identifying emergent themes in their sketches and notes.

4. Analysis and Discussion

In this section we discuss the data gathered through our study, starting with the automatically saved data from the pupils' game sessions (4.1), to end with ethnographic and co-design data (4.2). Finally, we propose a critical perspective on our data, regarding a hermeneutic perspective on CT for beginner programmers and future works regarding improvements of our prototype (4.3).

4.1 Quantitative Analysis of Auto-Saved Data

Each player starts by registering, entering a few non-sensitive data, and receiving a unique identifier number; the data requested in the registration form is limited to only first name or a nickname, self-reported programming experience (ranging from 1 to 5) and age, to ensure adherence to Danish GDPR rules. No sensitive or private data is stored on our database, we just use the unique identifier to "trace" the history of each player. When playing a level, every time the player runs the Blockly code, an AJAX call is sent to the cloud database and records: the player's id, the timestamp of the attempt, and the code, information about success and how many stars were awarded, and finally, information about the number and timing of clicks the player used to compose the code in each attempt. The automatic saving of game sessions allows us to perform offline data processing and analysis for each player, the most interesting of which are:

- number of attempts to win a level, and total time spent playing a level
- **play interval** of a level: i.e. first and last time a level was played
- how **continuous** were the attempts, calculated as

$$\frac{\textit{number of attempts at solving level N}}{\textit{number of attempts at any levels, during the play interval of level N}}$$

- number of times the mouse was clicked, in a single attempt, for a specific level
- the **click density** for an attempt, measured in clicks per attempt, calculated as:

$$\frac{\textit{number of clicks in all attempts}}{\textit{number of attempts at solving that level}}$$

For every level, we also calculated: the minimum, maximum, and average length of the solution, the average number of wins, and the average time spent by players in that level. Table 2 shows the overall results of all tests we performed so far, from August 2022 to March 2023; in Table 2, the time is measured in seconds.

Table 2: Overall results from all our tests

level	avg num attempts	avg num wins	avg time spent	avg continuous strategy	avg click density	min length	max length	avg length
0	2	1,26	41	67	2	5	8	6,25
1	3	1,26	636	62	5	5	7	5,75
2	6	1,6	897	65	10	7	17	13,07
3	11	2	1.187	55	7	4	15	8
4	4,2	1,53	923,53	53	12,44	4	16	10
5	2,4	1,26	772,26	50	7,15	6	11	6,66
6	3,73	1,06	246,93	67	9,63	8	12	10,7
7	2,33	0,86	183,2	74,03	10,96	9	12	9,5
8	2,73	0,8	209,13	67,36	10,75	7	13	9
9	2,6	1,2	273	62,42	8,7	4	16	9,09
10	8,6	0,8	611	71	16,95	9	20	15,37

We designed some of our indices to look at the *strategies* players adopted in their attempts. The *average continuous strategy* column in table 2 refers to how much a level was played without jumping to other levels, averaged over players. The *average click density* column attempts at estimating where players working on a level adopted a **think strategy** or more of a **tinker strategy** instead. A player can stop and think out a solution, before coding it with the blocks, while another might keep trying variations, relying more on the game to provide feedback: these two strategies define a spectrum that goes from **think** to **tinker**. The last 3 columns in table 2 refer to the length of a *correct submitted solution*, measured in number of blocks; levels with large span between min and max length should be considered more difficult to solve optimally.

We are aware of the small number of samples and our purpose is not to draw statistically significant conclusions, but instead to highlight how these findings relate to the analysis of the qualitative data discussed in the next subsections.

4.2 Observations of Gaming Sessions and Co-Design

During the gaming session, we saw that the students were very focused, so that it was hard to understand if they were having fun or not. In general, they played on their own, occasionally helping each other or calling us and their teacher for help. During the informal interviews conducted at the end of the gaming sessions, the pupils commented positively on the game. Most pupils said that the game was "fun" and three students even said "addictive" with a smirk, as they felt compelled to reach a 3 stars award on their solutions. This is confirmed by the auto-saved data, showing distinctively how the pupils played multiple times the same level to achieve higher scores. Moreover, most pupils said that they liked how the game was challenging and forced them "to think", a girl said that she liked how: *"it (the game) is challenging my mind, I can see myself playing on my mobile phone on the bus."*

During the co-design session, the mood changed dramatically, and the pupils were very active in sketching and cutting out paper, while socializing with each other in small groups. The design material they created was subject to a thematic analysis on Nvivo so to identify the most common experiences with our games and the most wished-for design requirements. In Table 3 we show the results of the coding of the material.

Table 3: Categories of Coding from Nvivo analysis of the pupils' design materials

Name	Files	References
Negative comments	14	18
Usability	19	46
turn	3	4
Speed	4	4
Commands	11	16
feedback to players	9	10
New features	3	3
Personalisation	6	6
Sound	6	7
more ingredients	7	9
layout-navigation	17	23
Characters	4	5
Time	7	8
multiplayer	3	3
live-game	2	2
Positive comments	14	20

The most typical positive comments included the graphics and the concept behind the game, which was defined as: “fun”, “self-explanatory” or “simple”. On the other hand, negative comments dealt with suggestions to improve the graphics, the mechanic and instruction code for making the robot turn, and the lack of space in the coding area.

Looking more in details into the usability category, different input was gained and divided into subcategories, the most represented being how to control of the movements and speed of the robot. In the subcategory *Commands* we have gathered comments about the size of the buttons, colors, and placement. Most pupils appreciated the star system, they found it motivating to retake the same level and improve their results; a few of them suggested to have more explicit information on how they can improve their score.

Under the category *New Features*, we have gathered all the suggestions regarding new ideas for new game releases, such as: personalization of the robot-character, creation of new levels, addition of sound and juice effects at level completion, like a chewing sound and/or animation of the sandwich being eaten. All the players wanted a broader selection of ingredients, more obstacles to avoid in the levels. Most pupils asked for having timed game sessions to measure how quickly they could solve the level, and in this respect, we discussed the possibility of having multiple difficulty levels so players could start playing freely, but when feeling more confident they could play the timed game sessions. Finally, all the pupils suggested to have a multiplayer modality, in which they could challenge each other or collaborate online in gathering the ingredients. An original proposal was that of transposing the game into a live-action role play game, where players compose the code and enact the robot’s actions live on a playground. One group also suggested the intriguing new name *Sandwich Maker*, where the word “maker” can suggest an automatic appliance or a cooking robot.

Pupils and the teacher saw learning potential in the game, as a tool for scaffolding algorithmic thinking, but also for training and refining learning at later stages.

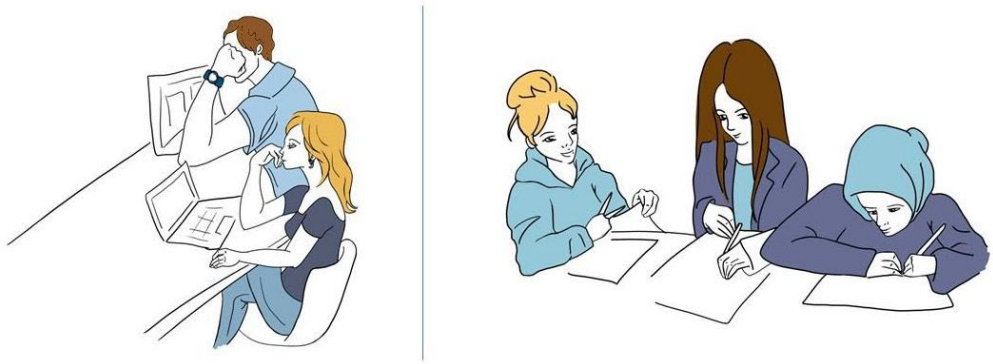

Figure 3: Drawings from gaming and co-design sessions

4.3 Critical Discussion

A suggestion made by several of the pupils was the wish for a larger coding area. On the face of it, this is a simple suggestion, highlighting an apparent lack of user-friendliness in the prototype design. However, the limited area for coding was intentional on our part, as we wanted the pupils to experiment with getting their code short, because a shorter code requires a deeper understanding of abstraction and generalization (Chongtay, 2022). For instance, a solution using *untilStepOn* loops would work even if the shop map is scaled up, while an hard-coded solution would not; in our game shorter code is usually better quality code. Therefore, we had hoped that a limited area for coding would naturally suggest that the code should not be too long. This hope is contradicted by our observations and the automatically saved data which show that the pupils tended to assemble long sequences of instructions, rather than create code with loops. These considerations point to a tension often present in programming classes: between pursuing programming learning objectives on the one hand and providing pupils with freedom to choose projects and solutions, supporting their feeling of self-determination and ownership, on the other hand (Bjerre and Dohn, 2018). Taking a step back, the issue here is also one of different values: the programming-internal values of abstraction and generality, according to which the best code is the one with the fewest steps, or the one covering the most cases. The values of user-friendliness and understandability, where longer code is often more intuitive and comprehensible. And potentially also values of sustainability: our analysis of the auto-saved code suggests that sometimes the players proceeded to “compress” their code, using loops as much as possible, in order to collect 3 stars. However, in so doing they hyper-regularized their code, making the robot perform inefficient moves, just to

make the code easily expressible with the available loops. This phenomenon is actually part of the gameplay of the more advanced levels in other games, like LightBot. The extra, unnecessary moves or rotations might have a negligible cost in our simple program, but this would not be the case if the program was instead run by a physical robot that would consume energy to perform useless operations.

One future use of our prototype that has become apparent to us in this study, is thus to form the outset for an in-class discussion of values in designing digital artifacts. This brings us back to our initial discussion of conceptualizations of CT: it is important that young people learn, not only to create digital artifacts, but to create ones that are appropriate for living in today's world, from an ethical, social, and environmental point of view. Moreover, from the analysis of the auto-saved data, we know that our players favor different problem-solving styles, such as various levels of continuity in solving a level, and the spectrum of think/thinker strategies. We could have easily enforced the idea of a best/optimal strategy, by demoting solutions that required many failed attempts, or forbidding to play the next level until the current is solved. Instead, we designed our game to support these personal problem-solving strategies, to communicate to the students that they can find their own place in the programming practice, and in keeping with the principles behind User Centred design. Our little coding example may be a concrete way to foster understanding of the larger concerns that need to be taken into consideration when developing technology, and the risks of focusing too narrowly on programming-internal values. In this way, our prototype can be used to support both cognitive and critical aspects of CT, in the framework suggested by Dohn et al. (2022).

5. Conclusion

The main contribution of our paper proposes an example for how to transpose the thinking behind algorithmic problem solving into game mechanics, embodied in a casual game. It also shows how the choice of a non-technical context can better support beginners in learning CT. Ongoing work focuses on improving the game's graphics, creating new sets of levels, and experiment with suggested re-designs. Our analysis of the play strategies and the feedback from the players, suggests that future work involves the creation of a level editor and enabling group-to-group asynchronous challenges, as in tools like Kahoot; this would make the game more open to user customization and extend the playability of our game.

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Kuxtal: Student Motivation Through Megagames in Higher Education Design Students

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Abstract: Megagames are an engaging combination of different game resources. They involve role-play, social connection, simulations, rules, economics, politics, decision making among others that are merged into an immersive narrative, all of which are essential applications of experiential learning. They can last from one day up to one month, they are known to be collaborative and can be played by several players at the same time. In education, collaboration between individuals is an integral competence that has to be nurtured among the academic community. During the game dynamics, multiple experiences, events, and actions are activated that enhance curiosity and emotions among students which, in turn, impact their motivation in the learning process. Wicked problems are undetermined problems that are resistant to change, possess a social and cultural context, several stakeholders are involved and overall are complex to solve. In this paper we explore 1) the use of megagames as a component to motivate student-learning of Higher Education (HE) students of the fourth semester of a degree in Design at the Tecnologico de Monterrey institution, located in the northwestern region of Mexico in the State of Sonora. We also 2) analyzed if research and action was triggered among students through the megagame, Kuxtal. The megagame, aims to promote student-learning through understanding wicked problems: that all living beings face in regards to water: its scarcity, its pollution and its mismanagement. In this qualitative study, we used Jones (2021) user guide for assessing components of the MUSIC model of motivation to understand empowerment, usefulness, success, interest, and caring. With the incorporation of megagames in the classroom, educators were able to promote student motivation and students engaged in research methodology, all while adopting small world-changing actions in their everyday lives. This paper aims to promote the advantages of using megagames as an educational resource in Higher Education creative fields such as Design, Architecture and Communication.

Keywords: Experiential learning, Higher education, Educational innovation, Megagames, Tec 21 educative model

1. Introduction

In order to achieve expected learning outcomes in Higher Education (HE) students in a Design major, the planning, the execution and the design itself of the course must not only be adequate for the intended targeted goals, but it must also be attractive for them. Added to the learning outcome, the incorporation of real-life problems that students can relate with can motivate them to become active participants in the solution to such regional, national or world problems today.

Nowadays, Higher Education institutions understand the importance of funding research and innovation projects by providing resources, infrastructure and tools to enhance Research and Development (R&D) efforts in order to participate in the global research community and contribute knowledge for a better society. With this said, research methodology is not known to be highly promoted in undergraduate courses for several reasons. According to Evans (2010), this is due to HE professors themselves having to produce research in tight turn-around times, conduct research projects and compete for grants while having to guide graduate students and carry out teaching activities all at once.

The active participation of undergraduate students in research activities can provide them with useful long-term skills that can be applied in their field of choice (whether it be in a professional setting) or in future graduate studies. Such added skills can range from lab techniques, theory analysis and comprehension, data analysis, project proposal development, independent and team work skills, to name a few (Petrella, 2008). As in all research, funding R&D projects at a HE level (be that in graduate or undergraduate programs) continues to be a source of conditions that restrain or push the work of the scientific community (Petrella, 2008).

2. Context

In Mexico, the situation of research and development becomes even more complex due to the nature of research practice in the country. The scientific community is constantly in a competition for the limited resources available to them for R&D projects through federal, state or private grants. The National Council for Science and Technology (*Conacyt* for its acronym in Spanish) is the leading provider of funding for HE institutions in the

country, being the Universidad Nacional Autónoma de México (UNAM) the nation's top research production university.

While research and development is not necessarily highly promoted in undergraduate studies, the need to do so is important to foster and cultivate a sense of curiosity towards research production in any field. In the case of the Arts, scientific production does.

With this said, the need for more promotion from professors, the limited funding for undergraduate research and the low motivation for research methodology among HE students in a Design course provided us with our driving question: How can we develop student-motivation among them for research methodology and motivate them in their learning process? and how can we motivate them to develop possible solutions for 'wicked problems' in their communities?

2.1 Student Motivation in Higher Education

Seifert (2004) notes that, in order to achieve student motivation in classrooms at any academic level, they must be provided with environments that invite creativity, a sense of autonomy, inclusion and education that lets students actively participate in the design of the learning process.

The task of increasing student motivation is often left to educators, which can lead students to be passive actors in the learning process. However, the willingness to learn, be curious and actively engage in the learning process must also come from within the students themselves (intrinsic motivation) (Williams-Pierce, 2011). According to Williams-Pierce (2011), the 'formula' to achieve student motivation at any level is non-existent, but some factors can come up as useful to do so. She notes that there are five 'ingredientes': 1) students must be willing to learn; 2) professors also have to provide proper rapport and guidance to students; 3) the content to teach must attract students interests 4) presented in a way that can be attractive to learners, all while 5) maintaining a welcoming and creative environment that promotes innovation among students and professors alike.

At a Higher Education (HE) level, student motivation can be achieved and retained. This is a pressing matter that schools should have as priority. Rizkallah and Seitz (2017) point out that there are stages in a student's journey through their studies, where institutions need to pay close attention to achieve their targets. Such stages for the authors are the following: discovery, establishment, engagement and future-driven stage. In all of them, the authors note that there must be proper guidance by faculty to enhance retention numbers.

At a classroom level, student motivation is more complex. Liu, Bridgeman and Adler (2012) mentioned that "college learning outcomes are much broader than what's captured by learning outcomes assessments. College learning covers learning in disciplinary subjects" (p. 360). However, the authors observed that, as expected, students that have more motivation can be able to increase their evaluation scores and their knowledge acquisition. When dealing with HE students, educators need to value opinions, inputs and student creativity. While acknowledging so, they can develop a motivation towards the expected outcome they face. And, by including games (in our study megagames) to the equation, it can be a useful resource.

2.2 Megagames in Higher Education

As humans, playing is an essential part of us. Playing is even older than culture, as animals also play (Huizinga, 1955). When playing, there is fun and enjoyment. The game, as a structured way of playing, has four characteristics: a goal, rules, a feedback system and voluntary participation (McGonigal, 2011). One of the types of games developed in the last decades is the megagame. A Megagame, is a game played by several to hundreds of people that are often organized into teams. Usually, teams of players take on specific roles. The duration of a megagame could go from a half day (a megagame is a bit like a board game) to a weekend, and could be split into turns (megagame assembly).

The games are designed to be challenging, interesting and fun. They usually simulate a complex social, political or military situation (megagame-makers). They generally involve a combination of board game-style mechanics and role-playing elements (megagame assembly). The game designer sets up the background and objectives and at the same time. Players have to oversee resources and work towards objectives (megagame assembly). Resources need to be managed as they are scarce, creating interesting decisions and strategy. Examples of restricted resources could be money, technology, information or materials (Rycroft-Smith, 2016).

Megagames, as many other types of games, can be used as an educational tool. There are several examples of its application at HE levels in different countries. One example is ALLIANCE, a political science simulation

megagame by Shawn Mcmillan (2015). Another example is the game "VIRUS: Bunny Apocalypse" by Ted Castronova. Both were played in the United States.

Another example was conducted in 2020 at Linköping University. This Climate Change megagame is part of an on-going research project that looks to propose discussion around the topic by engaging players in real-life experiences and role-play.

In Mexico, research of megagames is almost non-existent. Nonetheless, gamification has been previously explored in various studies, mostly conference proceedings on the matter (González & Montalvo, 2018). There have been electronic games created by nationals, such as Robledo-Rella's (et al., 2017) Cocogame, which was used by Tecnologico de Monterrey's undergraduate students and González & Montalvo's (2018) BluRabbits internet based platform also helps to create different types of learning experiences.

2.3 Wicked Problems in Higher Education

Cities all over the planet are facing several challenges known as Wicked Problems (Buchanan, 1992; Coyne 2005; Irwin 2011; Rittell & Webber, 1973). Climate change, drought, obesity, poverty, racism, waste management, homelessness, crime, loss of biodiversity and water insecurity (Sarni, 2021) are some examples of this high complex, unsolvable and undetermined (Rittel, 1973; Buchannan 1992) system problems which are interrelated, interdependent and impact increasing numbers of people and other living beings (Gideon and Irwin, 2021).

Coyne (2005) has pointed out the complexity of what Wicked Problems (WP) are. In his revision of Rittel and Weber's (1973) definition of such, where the authors note that these problems normally appear in a social context, Coyne notes the following regarding WP:

> *"[They] persist, and are subject to redefinition and resolution in different ways over time. Wicked problems are not objectively given but their formulation already depends on the viewpoint of those presenting them" (p.6).*

Lönngren & Van Poeck (2021) note that not only are these problems complex, but that their definition itself is not fully conceived by all in the same manner. This, they note, is the result of multiple theories involved and the lack of having a grounded consensus in what is and is not a wicked problem.

Ritchey (2013) also sees WPs as part of various areas and their planning. He provides a characterization of these by providing ten different criteria, which are the following: 1) They do not have one sole formulation; 2) They do not have rules that indicate when or where to stop; 3) Their solutions are better or worse; 4) They do not possess an ultimate solution; 5) WPs have attempts that has consequences; 6) WPs can have no solution whatsoever; 7) Each WP is unique; 8) A WP can be the result of another WP; 9) The causes of some WPs can vary; and 10) The end of a WP is not to be right or wrong, but to provide positive change for the specific WP. In addition, The author notes that WP "[are] ambiguous and associated with strong moral, political and professional issues" (p. 2).

In addition to this previous framework, Irwin and Gideon (2021) provide other relevant characteristics of WP: 1) they involve designed artifacts, communications, built infrastructure, technology, interactions and most importantly—people—which makes both their structure and behavior highly complex; 2) they reveal at different levels of scale, have multiple root causes and are interconnected among them; 3) it is important to consider other species and members of an ecosystem with conflicting agendas, affinities and dislikes; 4) they are governed by positive and negative feedback loops. Positive feedback occurs when a small intervention in the system quickly amplifies. Meanwhile, negative feedback involves attitudes, beliefs, values, behaviors and practices that represent ways of thinking and acting that affect the scenarios; 5) they cannot be solved from a fragmented disciplinary approach. It is necessary a multidisciplinary and holistic point of view or in other words, a systemic response; and 6) WP manifests in place, cultural and ecosystem-specific ways.

2.4 Water: A Wicked Problem From a Global to Local

According to THE United Nations Children's Fund (UNICEF) (ONU, 2019), 2.2 billion people do not have access to safely managed drinking water services; 4.2 billion people lack safely managed health services; water scarcity affects four out of ten people and eighty percent of waste water returns to the ecosystem without being treated or reused. The agricultural sector is the largest consumer of freshwater, responsible for almost 70% of water withdrawals worldwide. In Mexico, 60% of drinking water comes from surface water bodies. Of the main rivers, seven represent 71% of the country's surface water, located in the center and south of the country, while only

29% of the surface water is located in the north. Mexico is a country vulnerable to droughts with 52% of its territory located in an arid or semi-arid climate.

Hermosillo, the capital of the State of Sonora, is an emerging city with potential and a great opportunity to become a sustainable city. It is located in the northwestern region of Mexico. It has an urban population of 799,165 inhabitants and it is located in the Sonoran desert, which extends through the states of Sonora and Baja California, and through the southern states of Arizona and California in the United States. This desert is characterized by its high temperatures during the summer and low rainfall.

The city's challenge is related to its water security, being a city located in a desert climate and highly vulnerable to the effects of climate change. The growth of the city and the conflicts associated with the uses of the resource have led to a continuous search for new sources of supply. Nowadays, seventy one percent of the water used is extracted from the underground; this has caused a rapid depletion of water reserves. Climate change and water are interrelated WP where multiple stakeholders such as the public and private sector, non-governmental organizations, and civil society impact. If not properly addressed, the effects of climate change on water availability could have far-reaching consequences.

3. Methodology

Kuxtal was born from a Discipline Update Course *(CADI)* addressed to Higher Education educators organized by the Tecnologico de Monterrey HE institution in the summer of 2021. It consisted of knowing the methodology of megagames as an educational innovation strategy, so teachers could apply this playful resource in the classroom. Alejandro Andrés Iparraguirre, a professor at Universidad Nacional de Quilmes, a producer, designer and cultural manager of the video game industry, was the instructor who provided the tools to build the dynamics of a megagame (Narrative, Physical-Digital materials, Temporality, Role play, Set Up, Phases and Rules).

The project was a collaborative effort and was carried out over three days. Kuxtal, it was designed by seven professors from different locations and disciplines: Diana Cruz, Leticia Ramirez and Monica del Rosario Vargas from Monterrey, Camilo Duque from Leon, Edgar Ludert from Sonora Norte, Norma Ortiz from Santa Fe and Brenda Plata from Puebla, all of them Tecnologico de Monterrey campuses. Each of the members contributed with ideas that impacted on the elements that made up the megagame.

The megagame had three objectives: 1) Increase motivation of Higher Education students; 2) Increase awareness of Higher Education Design students over water issues locally and globally and 3) Develop research, reflection and action through the dynamics of a megagame.

We aimed to raise awareness among students about the problems related to water. Because water is the most vital element for existence, we decided to name this megagame Kuxtal, which means ¨life¨ in the Mayan culture. The game's narrative consisted in the simulation of a parallel world divided into 4 towns (north, south, east and west) which had become desert and hostile. This had given rise to the annihilating gray monster and its retinues, the humanoids, detestable beings who would do everything possible to keep Kuxtal dry, polluted and lifeless. Once the affected areas are removed, the monster and their allies are defeated. In other words, the teams should use "constructive cycles" to recover the availability, well-being, health and conservation of water.

Kuxtal involves real-life issues and science-fictional elements in order to provide students an immersive narrative that develops their critical-creative thinking skills and promotes their interest in research and development activities. The physical game itself consisted of original materials designed with the aid of Artificial Intelligence (AI) to create the pilot version (1.1) of the game.

Kuxtal gaming consists of 8 PHASES: 1.Beginning of the journey; 2.Pay Kux; 3.Towns dice; 4.Monster and Shaman; 5.Purchase of cards; 6.Cards activation; 7.Healing Kuxtal; 8.End. There is a loop between phase 2 and 7, once Kuxtal is healed completely, the last phase is enabled. The overall game had players divided into teams (towns) during six days of play in synchronous (in the classroom) and asynchronous (remote) time. The teams had to earn Kux (water stone tokens) through service learning, research, and critical thinking activities to get activation cards; which promote action (Ex: water a plant in your community at night), research (Ex: what is virtual water and mention 3 relevant examples), reflection (Ex: water, just as it is life, is also death) and exploration (Ex: explore rain harvesting systems and select the most appropriate for your community) (see Figure 1).

The students transform into *the guardians of water* and randomly into the *shaman* and the *gray monster*. Daily, the elements are set up on the floor, including the map, *Tuccum* cards (gray cards), *Kaxan* cards (yellow cards), *action-reflection-research* (dark and light blue cards) , town dice and the monster and shaman summon tokens.

The guardians have to validate the cards by presenting their corresponding evidence that is registered by the teacher (see Figure 2). The game ends when the four towns remove the 20 gray Tucuum cards from Kuxtal.

Figure 1: Kuxtal mega game pieces and water stones

Figure 2: Kuxtal megagame reflection cards

3.1 Game Rules and Mechanics

3.1.1 Lot

Kuxtal, a world that once was blue and full of life, today is gray and dry thanks to the gray monster and its followers, the humanoids, despicable beings that are against water and all living things. These feed on pollution, droughts and all those acts that harm the most important living being: water. But there is hope! The last 4 guardian villages will need to ally with the shaman, together with his divine rituals, will fight to heal Kuxtal and turn it back into an oasis full of life.

3.1.2 Temporality

The game lasts about a week, between 3 and 5 hours in total. 30 synchronous minutes and 30 minutes asynchronously are played daily depending on the time assigned by the teacher.

3.1.3 Materials

Game element	Description
Kuxtal Map	1x1mt printed canvas with the 4 territories. This is placed at floor level. Educators can choose the size of the printed map so it conveys its budget and space.
1 Towns dice	Tetrahedron dice that contains 2 times each of the towns. This is used to select which town will control the monster and which town will control the shaman each day.

Game element	Description
Monster tokens	Contains negative effects that affect Kuxtal.
Shaman tokens	Contains invocations that give Kux to the guardians of water.
20 action cards	Dark blue cards that imply an embodiment of activity, mobility, participation of an external person, among other traits.
20 reflection cards	Light blue cards with quotes that inspire reflection about water.
20 research cards	Light blue cards that involve doing basic research about a concept, case study, author, information, etc..
20 Kaxan exploration cards	Yellow cards that need artifacts to be activated. Once flipped, these cards give special powers and Kux.
20 Tucuum cards	Gray cards that need to be removed from the map, each one has a symbolic text that represents a negative effect.
200 Kux	Stones of different shapes and blue colors. They can be obtained by activating and achieving the card's commands. (There is freedom to use any kind of materials)
1 box	Container that stores all the pieces.
1 blackboard or 1 Laptop	It is used to register the activated cards, either during the current day or the next day. If the educator has a computer, it is feasible to carry out the registration digitally.
1 pencil	Any instrument used to record information.
1 shamanic collar	Optional, works for role play and personification.
1 monster hat	Optional, works for role play and personification.

3.1.4 Roleplay characters

GUARDIANS OF THE WATER	During the game, all the students transform into the guardians of the water and they are divided into the four different towns. Its aim is to carry out positive actions to heal the Tuucum areas. As a community, they decide how they use their Kux, and their tools to get cards. They must contemplate that they need to pay 1 Kux daily to be alive and continue playing.
WATER ANNIHILATOR MONSTER	Each day, a town becomes the monster, which will affect Kuxtal with negative points dictated by its dice.
SHAMAN	Every day, a town randomly summons the shaman. He decides which town (other than the shaman's) will benefit from the ritual dictated by his dice. The town, together with the shaman, will carry out the ritual to obtain Kux.

3.1.5 Setup and phases

SET UP	Students are divided into 4 teams (there must be a balanced number of water guardians per town. There may be a difference of 1 person in some teams) Teams choose the name of their town Place the map on the floor Place the Tucuum and Kaxan cards randomly on the map. Place on the blackboard (physical or digital) the 4 towns and their respective members. Place the light and dark blue water card decks into the edges of the map Place the additional elements near the map: The towns dice, the summons of the shaman and the monster.
PHASE 1 **PAY OF LIFE**	To start the game, each player must pay 1 Kux daily to stay alive. If some of the guardians don't have Kux, they can borrow from other towns.
PHASE 2 **TOWNS DICE**	The town's dice is rolled to choose who will activate the monster and who the shaman.
PHASE 3 **MONSTER AND SHAMAN**	The town with the monster rolls the dice to choose where the negative points will affect. The town with the shaman choose one random invocation and applies its Kux reward.
PHASE 4 **PURCHASE OF CARDS**	The town in turn will choose which cards they want to buy. The teacher will collect the Kux corresponding to the cost of that cards. Ex. Town X buys 2 action cards (2 + 2) and one reflection card (1) giving a total of 5 Kux. This stage is until the 4 towns purchase cards.
PHASE 5 **ACTIVATION OF CARDS (ACTION, RESEARCH, REFLECTION, EXPLORATION)**	The town in turn will choose which cards want to activate. The team reads the description of the card aloud. Ex. Town Z activates a reflection card (+3), discussing what the card command is. Likewise, they activate an action card (+10), which involves watering a plant in their community. The teacher will reward them with 13 Kux. Action and research cards will generally be charged the next day, cause these activities are planned to be performed asynchronously. If a town has any tool derived from the action cards, this turn it will be able to access the exploration or Kaxan areas indicated on the yellow cards on the board. As long as the people do not obtain any tools, they will not be able to access the Kaxan areas. This stage is until the 4 towns activate their cards.
PHASE 6 / RELEASE TUUCUM AREAS	The town in turn will decide how many Kux will be used to eliminate the gray cards or Tuccum zones in the map. If a town is left with a zero Kux balance, they must borrow from the other towns to continue playing the next day. This will happen only 2 rounds.
PHASE 7 **END OF THE GAME**	The game ends when the four towns remove the 20 gray Tucuum cards from Kuxtal. Each town will make a final reflection on the experience that the megagame left them.

3.2 A Megagame in Tecnologico de Monterrey

The Architecture, Art and Design School at Sonora Norte campus is focused on developing projects that impact the real-life scenarios of students. Therefore, we addressed WP with design approaches. The design praxis that we are trying to promote is the one that not only sustains but regenerates. Through our practices and interventions into culture, design can make a positive impact into our immediate local context.

It was tested during the second and third week of the Thinking and Creative Process course in the fourth semester of the Industrial Design degree. This topic lasts 5 weeks and is research oriented. This 2023 is the third year in which the water challenge is promoted on a national level. This means that we have to create projects that attend to problems related to water. Some examples that students designed are; an hydroponic garden that reuse gray water; a public fountain that collects rainwater and a water filter saver that is oriented to parents that want to educate their children around ecological practices. This initiative impacts directly into the Sustainable Development Goals (SDGs) 6; Clean water and sanitation, however it also relates to SDG 3 (Good Health and Well-Being), and SDG 11 (Sustainable Cities and Communities).

The participants were 24 students from Tecnologico de Monterrey Sonora Norte campus. Of these students, 2 were male, and 22 were female. The students belonged to the fourth semester of the Industrial Design degree. To analyze motivation, we administered the Brett D. Jones (2021) MUSIC model, which can be used in any subject area at any grade level (a) to design instruction that motivates students, (b) to diagnose motivational strengths and weakness of instruction, and (c) to research relationships among factors critical to student motivation. The five principles of the model are as follows: "The instructor needs to ensure that students: 1; feel empowered (...) to make decisions; 2. understand why what they are learning is useful (...); 3. believe that they can succeed if they put forth the effort required; 4. are interested in the content (...), and 5. believe that others in the learning environment (...) care about their learning and about them" (Jones, 2018, p. 9).

The contextualized version of the MUSIC model had 26 items and were divided into five components: Empowerment, Usefulness, Success, Interest, and Caring. Empowerment and Usefulness use five questions, Interest and Caring six questions and success four. All items used a 6-point Likert scale describing 1 (Strongly disagree), 2 (Disagree), 3 (Partially disagree), 4 (Partially agree), 5 (Agree) and 6 (Strongly agree) (see Annexe 1). The data obtained was kept anonymous so the answers to the survey items could not be linked to individual participants.

4. Results

Once the survey of 26 items was conducted, we analyzed the information collected and were surprised by the answers. The answers related to our first objective (the use of megagames to enhance student-motivation) returned favorable towards the methodology used in the session for the study.

1.The course activities catch my attention.

2.I have the opportunity to decide for myself how to achieve the objectives of the megagame.

3.In general, the activities of the megagame are useful.

4.The teacher is available to answer my questions related to the activities of the megagame.

5.Megagame activities are beneficial to me.

6.The teaching methods used in this megagame call my attention.

7.I am confident in my ability to successfully perform the activities of the megagame.

8.I have the freedom to carry out the activities of the megagame in my own way.

9.I enjoy the teaching methods used in this megagame.

10.I feel capable of meeting the academic challenges of the megagame.

11.The teaching methods involved me (engage) actively in the megagame.

12.I have different options to achieve the goals of the megagame.

13.I enjoy megagame activities.

14.I consider myself capable of getting a high rating in this megagame.

15.The activities of the megagame seem interesting to me.

16.The teacher is willing to help me when I need it.

17.I have control over how I learn the contents of the megagame.

18.Through the megagame I have felt that I can successfully carry out the activities.

19.I consider the megagame activities to be relevant to my future.

20. The teacher cares about my performance in the megagame.
21. I will be able to use the knowledge gained in this megagame.
22. The teacher is respectful to me.
23. The knowledge gained in this megagame is important for my future.
24. The teacher is friendly
25. I think the teacher cares about how I feel.
26. What I am allowed to do in this megagame is flexible.

Figure 3: Survey questions for participants based on the Music Model (Jones, 2021)

For our first inquiry in the study (do megagames motivate student-learning in a Design degree in HE?), the participants answered in favor of megagames as a motivation tool for their learning process. For example, statement 9 (I enjoy teaching methods used in this mega game) showed that 17 out of 24 participants strongly agreed with it (see Figure 4). While 3 agreed, 2 partially agreed and only 1 was in disagreement and another one strongly disagreed with the statement. Answers were almost similar in statement 6 (The teaching methods used in this megagame called my attention): 18 strongly agreed, 4 agreed, 1 was in disagreement and another one strongly disagreed (see Figure 5). In addition, statement 5 (Megagame activities are beneficial to me) were answered the same as in statement 9.

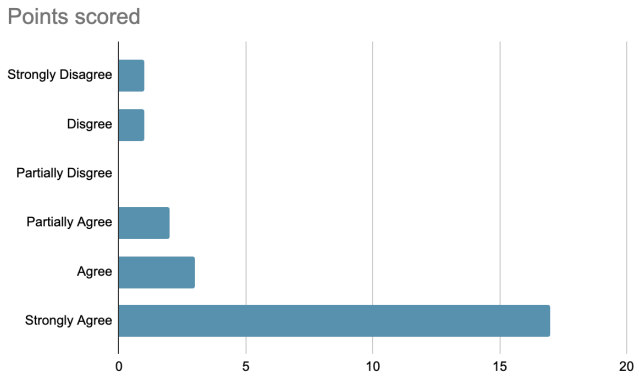

Figure 4: Graphic representing participants answer to statement 9 (I enjoy the teaching methods used in this megagame)

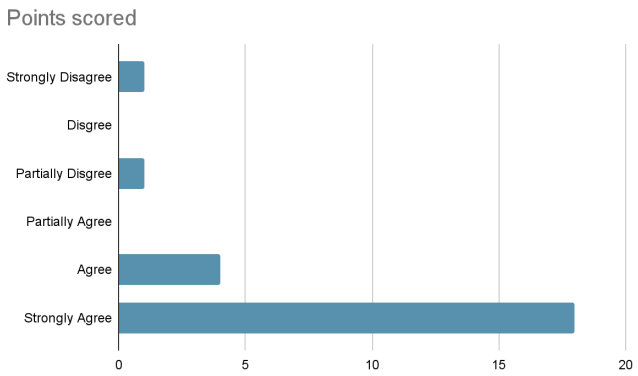

Figure 5: Graphic representing participants answer to statement 6 (IThe teaching methods of the megagame call my attention)

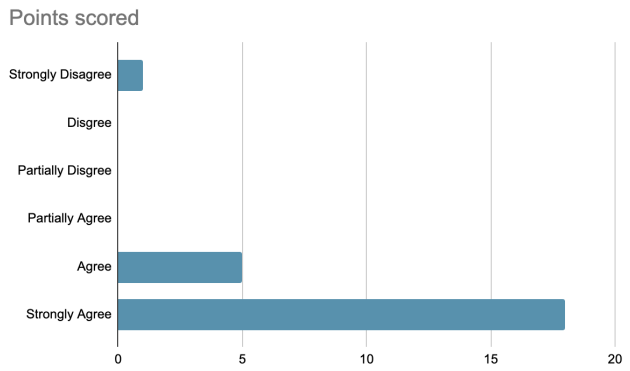

Figure 6: Graphic representing participants answer to statement 21 (II will be able to use the knowledge gained in this mega game.)

On the other hand, the answers to our second objective (if research and action was developed among students through the megagame), the responses from the participants on statements 19, 21 (see Figure 6) and 23 offer an insight on how the participants viewed the overall activity (which involved a megagame and research methodology) as useful towards their future activities. We interpreted this as a positive attitude towards not only the research methodology and the megagame itself, but as a useful tool and methodologies for students' future endeavors, whether in research projects or in their decision-making.

5. Conclusions

Megagames can be a playful response and approach to the understanding of wicked problems. Inside the classroom, educators can call educational innovations that impact not only in how the contents are shared, but in the motivation of students, so they can fully get involved in the phenomenon and its research process. Kuxtal was an opportunity to trigger collaboration, play, critical-creative thinking and actions that impacted on the real-scenarios of students, on their immediate context, community and discipline. This is an invitation to other educators that want to create immersive learning experiences and divergent methodologies that motivate students to think, learn and act. We believe that the process of the game creation could be highly enriched by the participation of multidisciplinary backgrounds educators.

In addition, we suggest further studies of the design and implementation of megagames in Higher Education (HE) scenarios, whether in an Arts undergraduate program or another program that requires students to collaborate and create solutions through serious play, research development and involvement with their immediate communities, all while reaching target goals in their learning outcomes. This, especially, should be explored as a useful alternative to motivate students in HE to participate in the research community at an undergraduate level and get involved in the solution of wicked problems. Even though this megagame was tested only once, it showed promising results. Finally, Kuxtal is an open source megagame that can be downloaded (spanish version) in the next url https://tinyurl.com/kuxtalmegagame so educators can print and use this water awareness research kit in their classroom.

Declaration of interest

This is to acknowledge that the authors report there are no competing interests to declare.

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History and Cartography Meet Youth Through Digital Technology

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Abstract: Through collaboration between the Onassis Foundation, the Historical Archive of the National Bank of Greece, and the Vocational Senior High School of Kamatero, an innovative digital project was developed that is both trendy and geared towards youth. This project showcases how a concept aimed at emphasizing the historical significance of the Capital of Greece inspired students to merge the disciplines of Computer Science and History, resulting in the creation of a 3D game on a popular platform. Additionally, this project demonstrates how Project-based learning can be achieved through collaborative and inquiry-based learning, real-world connections, initiative, and the satisfaction of creating something new. The impetus for the cooperation was the Panhellenic Student Competition of the Onassis Foundation, "Hack the Map: Imaginary Worlds." This competition invited schools to promote the cultural heritage of Greece, especially cartographic exhibits/evidence of the old days, through students' digital projects. The Historical Archive of the National Bank of Greece, which is a significant resource for studying Modern Greek History through primary sources, reached out to the Vocational Senior High School of Kamatero, located in the western sector of Athens, to work on a project. The school has an IT department, among other disciplines. In close collaboration, they developed a scenario that is about the civil war that occurred in Athens during the Interregnum period (October 1862-October 1863) after the dethronement of Greece's first king, Otto I. The scenario highlights the bloody events that took place between political factions in the city. In these conflicts, the implication of "Kyriakos," a dangerous leader of robbers, is a paradoxical historical event that stimulated the 2nd-grade Informatics students' imagination. Therefore, they created a 3D digital game entitled "Thieves and Policemen in the newly established Greek city-state: Iouniana." This presentation intends to demonstrate how the students' team of the Vocational School of Kamatero rebuilt Athenian monuments related to Kyriakos' action in a 3D environment; how they reconstructed the cartography of the capital's center during the second half of the 19th century based on these monuments and how they utilized digital resources (maps, photos, and texts) and books proposed by NBG Historical Archives; how a single player, via Kyriakos' persona, has to accomplish missions-battles and match parts of Athens' map of that era; and finally, how students narrated a historical event in a game constructed in Roblox platform inviting other young people to involve history knowledge.

Keywords: Project-Based Learning, 3d game, Historical cartography, Game based learning (GBL), Civil War

1. Introduction

Vocational Senior High School (VSHS) of Kamatero locates in the western sector of Athens. Its educational sectors of Electricity, Mechanisms, Healthy, Economy, and IT train and teach students who dislike theoretical disciplines. However, they must study History, Sociology in the A' Class, and Modern Greek Language during all their studies. Most of them belong to folk families with low incomes, and in many cases, they face social, emotional, and thus educational difficulties. School is essential for these students, although they need to realize it. That is why teachers implement pedagogical methods such as projects focused on teenagers' interests, educational visits, and digital technologies to reveal capacities and skills, helping them to feel creative, self-confident, and happy. By these principles, the Vocational School of Kamatero develops cooperation with renowned Institutions like the Historical Archive of the National Bank of Greece.

The National Bank of Greece (NBG) is the first credit institution in the country and the oldest in operation today. Its history intertwines with the economy and all the aspects of the history of Modern Greece. Rescuing its history and essential archival material, NBG created the Department of Historical Archive (HA/NBG), for which the Bank has shown special care since its establishment. In the archives of NBG, the economic history of the modern Greek state and essential aspects of its political, cultural, and social history have been recorded. The Historical Archive allows access to its archives, which currently cover the period from 1841 to 1966, and to originals or copies of archives of other institutions and personalities that have come into its own. Today, it is active in archival, historical, research, publishing, and educational work and is a pioneer in applying new technologies to manage

its archival material. The Department of educational programs aims to activate students' interest in history and significant historical evidence of Greek cultural heritage.

In this context, the Vocational School of Kamatero holds a creative relationship with HA/NBG due to its educational programs. So, when the Onassis Library of Onassis Foundation proposed the HA/NBG participate in its Panhellenic Student Competition "Hack the Map: Imaginary Worlds" as a cooperating body providing students with supporting material, the head of the Department of educational programs of the HA/NBG and her colleagues firstly proposed to the Vocational School of Kamatero to deal with scenarios based on NBG historical sources. When the School decided to participate and chose a scenario, HA/NBG provided information material (various archival digital records).

Onassis Library organized this Competition to showcase the cartography of Athens during Modern Times and familiarize students with that. On the other hand, HA/NBG provided scenarios and evidence highlighting the establishment of the National Bank and the modification of its central building in a historical street (Aiolou) in Athens and connected to significant historical events of the Capital. All these built a cooperative bridge because the Panhellenic Competition was the impetus for the team of the Vocational School to construct a digital 3D game. HA/NBG provided three scenarios concerning the political and cultural life in three different periods of Athens; two of them concerned historical events of the 19th century. Students and their educators studied the historical scenarios and sources of HA/NBG. Then, they decided to work with the period of "Iouniana," a conflict appropriate to base upon the story of a digital game.

1.1 Historical Context

Iouniana happened during the Greek Interregnum between the exile of Otto I and the enthronement of George I (1862-63). After Otto's exile, the Triumvirate of Greek politicians (Benizelos Roufos, Konstantinos Kanaris, and Dimitrios Voulgaris) who had taken the lead, formed a temporary government and announced elections for the convergence of the so-called *Second National Assembly of the Greeks in Athens.*

This National Assembly was divided into two large political formations, the "Highlanders" (greek: "Oreini") and the "Lowlanders" (greek: "Pedini"), names that allegedly referred to how the delegates sat in the seats of the National Assembly and indirectly reminded the corresponding factions of the French National Assembly (*La Montanagnards - La Plaine*). Significant politicians of the Highlanders were Roufos, Kanaris, Koumoundouros, and others. The strong leader of the Lowlanders was Dimitrios Voulgaris. The proxies who made up the National Assembly failed in their task and with their omissions, their political and party passions steadily led Greece to anarchy and the civil war of the "Iouniana" (probably "Junians" in English <June 1863), which was fought in the streets of Athens with hundreds of dead and wounded. Among both opposing armies were Athens' citizens and gendarmerie and military units. Conflicts escalated in front of the National Bank's headquarters in Athens. Lowlanders guarded the building of NBG after Georgios Stavros' request (Stavros and Voulgaris were political friends). Stavros was afraid of the looting of the Bank, which could lead Greece to bankruptcy.

Studying the sources of NBG, a historical paradox was revealed. A sketch of a contemporary newspaper depicted the leader of Lowlanders, Voulgaris, allegedly talking (making a deal?) with a very dangerous bandit, the chief of a gang named Kyriakos (https://padlet.com/chrysalenabw/padlet-yiccul549e157eum).

Kyriakos supported the Lowlanders because he had been arrested due to a Highlander's hostile policy against thieves. After a few months of imprisonment, Kyriakos was set free but continued his action in the villages east of Athens. After a second arrest of Kyriakos and his gang, he is led with a convoy of gendarmes to the city's center to put him in jail. However, the gendarmes made a deal not to unarm the thieves. Gendarmerie supported the Lowlanders, and there was a secret order to free Kyriakos. When the convoy arrived at the Petraki Monastery (nearby Palace), Kyriakos was fortifying himself with his men. This event terrified citizens, who took their arms to guard their property or left the city. Kyriakos was now free to enter the city and be integrated into the Lowlanders' army; Kyriakos, with 70 men of his, looted the city like other gangs during June 1863. The first armed skirmish between opposing factions happened on Aiolou Street, in front of the Saint Irene church, leaving many victims. After that, the gang of Kyriakos moved to Plaka, near Adrian's Library. One of the following battles was fought in front of the Palace. Aristidis Kanaris, son of Konstantinos Kanaris, military officer, and Highlander, who defended the Palace, was killed there.

Amazingly, here is the highest paradox: when the Gendarmerie with Lowlanders guarded the NGB, they were attacked by a military corps of the Highlanders, who wanted to take control of the Bank. At that crucial event, Kyriakos helped Lowlanders, but in this chaos, he or some of his men tried to rob the Bank (HHN: 2000).

All these events of “Iouniana” were the raw material for the Imaginary World (script and construction) of the 3D game "Thieves and policemen in the newly established Greek city-state: Iouniana."

2. Game Description

2.1 Main Scenario

Thieves and policemen in the newly established Greek city-state: “Iouniana", is an online role-playing game on the Roblox platform. The main action is set in the historical center of Athens during the Iouniana events (June 1863). The hero of the game, a teenager of 2022, is teleported through a time portal (via his historical book) to Athens in 1863 in front of the Palace (nowadays known as the Greek Parliament) dressed like a man of that age. However, as a modern entity, he is unaware of essential information that he hears from his surroundings in the game or from an omniscient informant narrator assistant (a voice). The voice informs the player about the political situation. It explains his involvement in the running events and at each level, assigns tasks, gives direction, and provides him with information about the monuments he encounters. The goal is to win the battle, earn points and find torn map pieces to complete the game.

2.2 Game Levels

The game was developed in 4 levels. Each one demonstrates a distinctive monument of the battle area. The levels follow the route taken by archrival Kyriakos to lead him to the final battle in front of the building of the National Bank of Greece.

Each level has its difficulty.

- First Level - Petrakis Monastery (Difficulty → Easy, Map pieces 3)

The player must fight against two kinds of enemies (the two Guards and the five highlanders) to gain points. The fight takes place at the side of the Monastery. After that, he must find Dimitrios Voulgaris (chief of Lowlanders) to work out a deal: Voulgaris asks for help (to collect the three hidden torn map pieces). The player must proceed to the portal when he reaches all level goals.

- Second Level - Saint Irene church (Difficulty → Normal. Map pieces 3)

- Part 1

The player stands before Saint Irene, and the voice guide is there to inform him that he must collect three more hidden torn map pieces in the area before proceeding to the second part of the level.

- Part 2

The player reaches the Mosque of Tzistarakis/Library of Adrian, where 5 Highlanders and 4 Guards have defeated some members of the Lowlanders. The player needs to defeat them before proceeding to the third level.

- Secret

Near the Mosque of Tzistarakis/Library of Adrian is the Tower of Winds, where the player can walk by, and a cut scene will play, revealing a secret achievement.

- Third Level - Greek Parliament (Difficulty → Hard, Map pieces 1)

Fight at the side of the Palace. A new kind of enemy will appear named the Elite Guard; he does significantly more damage than normal ones. After defeating all the enemies, he proceeds to a fast travel route with the help of the voice.

- Last Level - National Bank of Greece (Difficulty → Challenging, Map Completed)

The final level is outside the NGB, in front of Loudovikos Square. At this point is the last interaction with the voice assistant, which will warn the player about the final stage. The most glorious battle occurs, and the player ends up versus a large group of enemies. After defeating them, he will step on the designed pad to play the final cut scene and complete the game.

2.3 Features

The game was created based on the idea of the potential of the character’s design and abilities. Therefore, was incorporated the following features that have a major impact on the character’s functions:

- Vitality: Increase the character's Max Health Power <HP>
- Offense: Increase the character's Attack Damage <AD>
- Blessing: Saves the character from dying every 2 min, recovering an amount of his max health by the voice's help
- Ability: (Under construction)

The game has also a currency that can be exchanged for new upcoming features in the game, such as clothes, skins, weapons, effects. These items could be purchased from the market areas that will be around the map, the locations will be marked so that each player can find them on their way through the story.

The idea came from the "robux" used by Roblox players, the currency of our game is gold pieces dropped as loot by enemies.

3. Pedagogical Goals

The initial goal of the 3D game project was to highlight the historical cartography of Athens. However, the critical objective was to foster collaborations that help cultivation of the youth's historical consciousness, improve educators' teaching methods in schools and museums, and sharpen the perception of future citizens regarding the built environment and visible monuments. (Αλτάνης: 2019).

Moreover, creating a 3D game serves the policy of the Vocational School of Kamatero to implement modern pedagogical methods integrating collaborative and inquiry learning and digital technologies (Ren:2019). So, we participate in relevant programs and competitions. Otherwise, a formal Project lesson prepares the students of A class for project work.

So, more specifically, the pedagogical goals who contributed to this project were:

1. Benefits for educators:

1.1 Training educators:

- To become acquainted with new technologies in project development through seminars offered.
- To apply project-based learning and game-based learning combining the disciplines of IT and History.

1.2 Removing teacher burnout risk by breaking classroom routine and providing new challenges in their disciplines (history and IT) (Farber:2000).

2. Benefits for the students

2.1 Knowledge

- To connect knowledge with life and activate the student's involvement in learning according to Dewey.
- To learn how to plan and accomplish a goal/project through project-based learning according to Kilpatrick.
- To apply the exploratory approach to learning through well-organized historical sources.
- To apply digital knowledge that students had already reached on their own (use of Roblox)
- To get acquainted with innovative digital tools and techniques.

2.2 Application and creativity

- To visualize ideas by using their knowledge and imagination.
- To encourage narrative capacity and apply cinematographic techniques.
- To bring out students' talents.

2.3 Affective objectives

- To harness unique skills – abilities that make them feel creative and self-confident.
- To improve communication and empathic skills through Collaborative and Peer Learning.
- To cultivate personal relationship of trust and esteem between educators and students.
- To learn to work in a democratic environment.

3. Benefit for the player

- To cultivate historical consciousness, cultural awareness, and civilian activity.

- To urge students to study and interpret history through sources.
- To get in touch with the cultural elements of the new Greek world.
- To understand the role of a Bank for the political and economic life of a modern state.
- To realize what a civil war cause.

This project won 1st Prize in the “3D Game” category in the student competition of the Onassis Foundation. Therefore, the most outstanding award was completing a challenging project in a limited timeframe.

4. Methodology

Basically, the working team applied the Project-based learning methods. That means collaborative group learning, inquiry, and discovery learning and completion of a meaningful project. However, a digital project based on a screenplay requires the application of a specific methodology (Prieto de Lope: 2015).

The methodology chosen for the development of the game is the Scrum methodology. Scrum is a management framework that teams use to self-organize and work towards a common goal. It describes a set of meetings, tools, and roles for efficient project delivery.

The students were divided into groups, each undertaking to implement part of the project. Therefore, the following groups emerged: archival material search team, script writing team, 3D model creation team, programming team, and project presentation team. Collaborative platforms such as Discord, google docs and social media were used for communication between the groups.

Stage 1 - Research and collection of material

The Department of Educational Programs of NBG/HA carried out thorough research and prepared rich educational content regarding elaborated texts written in order to outline the historical context, digital archival primary sources about the places and times to which their proposal scenarios referred (original excerpts of old books, photographs, maps, postcards, architectural drawings, worksheets, bibliography, and other educational resources in order to encourage, inspire and support students to the search and in-depth study of the main topic. All the relevant material was uploaded as a padlet to an open-access educational platform, Classroom, aiming at providing students and professors with complete and more direct services.

Stage 2 – Training through Seminars

Teachers involved in the "Hack the Map -Imaginary Worlds" Competition needed further training. Therefore, they attended webinars organized by Onassis Foundation to provide assistance and know-how to students and teachers. The following webinars were attended:

- Create 3D models for fantasy worlds
- Apply color and textures to 3D models
- Generate motion for 3D models (animation)
- Build your animation (gif)
- Integrate 2D and 3D elements into game engines - Q&A

Education on issues such as copyright recognition and management, digital storytelling techniques, 3D Game creation, and good practices in creating digital worlds was also deemed necessary. Thus, educators followed posted videos by Onassis Foundation on the relevant topics.

Stage 3 - Human resources

Teachers who responded to the first call of Onassis Competition motivated colleagues and students to participate in this project: a teacher of History and three teachers of Information Technology (IT) formed a team of educators who invited students and informed them about the Competition and the related scenarios of HA/NBG. After that, some students of the Second grade of the IT sector and students of the First grade during the school year 2022-23 participated in constructing a 3D game. They all had high digital literacy, and some had complex learning difficulties. The students grouped into work teams, each undertaking to implement part of the project. Therefore, the following groups emerged: archival material search team, script writing team, 3D model creation team, programming team, and project presentation team.

Stage 4 - Scenario selection – writing new scenario – character selection.

Firstly, the team of educators and students studied the scenarios of HA/NBG and chose the event of Iouniana. These events became the scenes of the game. By studying the sources connected to Iouniana, the team decided

to write a new script based on the bandit Kyriakos' story. The skirmishes and battles he may have been involved in became the scenes of the script. The scenario presents the events in the true chronological order. Around Kyriakos is depicted Highlanders and Lowlanders and as individuals the politician Voulgaris, Normal Guard and Elite Guard.

Stage 5 - Enrichment of sources based on the final scenario - world construction.

Once the scenario was decided, it was necessary to find more sources to reconstruct the monument and Athens's cartography in 1863. The material of HA/NBG and the book of Tsiomis (Τσιώμης: 2021) were the essential sources. Many photos, etchings, and paintings from the internet were also used as references for the modeling. By consulting the maps, students proceeded to map the imaginary digital world. The construction of the buildings and characters of the game was based on photographic material collected.

Stage 5.1 World Construction

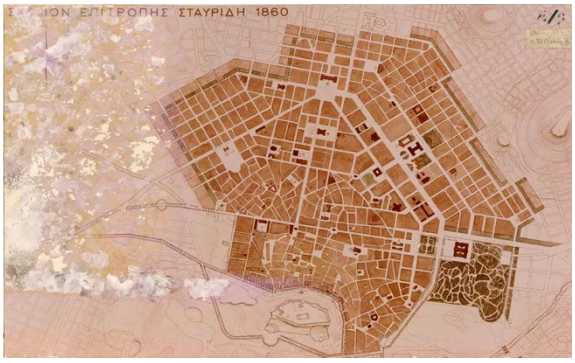


Figure 1a: Urban plan of the city of Athens by the Stavridis committee (1860)

Figure 1b: Digital model of the city of Athens

Stage 5.2 Building construction

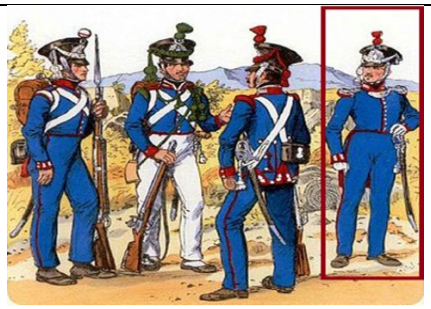
Greek Parliament, Petrakis Monastery, Saint Irene church, Mosque of Tzistarakis, Library of Adrian, Horologium of Kyristos (also known as the "Tower of the Winds"), and the building of National Bank of Greece was designed and built piece by piece. During the construction of the buildings, attention was given to every detail. The challenge was to make them look identical to the originals so that when the player is in the city center, he can recognize them and recall the information he heard during the game.

Real Monument	Description	Digital Model
Figure 2a: Petrakis Monastery	The Petraki Monastery or Holy Incorporeal Taxiarchs, is a medieval Byzantine church. This 10th century Byzantine Temple has been in continued use except for the period between 1500 and 1673, when it was abandoned.	**Figure 2b: Petrakis Monastery**

 Figure 2a: Greek Parliament	It's built atop the hill of Bubunistras. The palace designer was Friedrich Von Gertner, architect of the Bavarian court. On February 6, 1836, the foundation stone was laid, following Otto's order. Today it is the Greek Parliament, a timeless symbol that is part of the collective memory	 **Figure 2b: Digital model of Greek Parliament**
Real Monument	Description	Digital Model
 Figure 3a: Mosque Tzisdarakis / Adrian's Library	Mosque Tzisdarakis was built in 1668-1670, is located in the northern part of the Roman Agora. It was built on the ruins of a three-aisled basilica of the Middle Byzantine period. Andrians building was a big library in ancient Athens. It was founded in the 2nd century. Its largest part was demolished by the Heruli's looting in 267.	 **Figure 3b: Mosque Tzisdarakis / Adrian's Library**
 Figure 4a: National Bank of Greece	The building of the National Bank used to be the house of Kyriakos Domnados, at the corner of Aiolou Street and today's Georgiou Stavrou. The bank was founded in March 1841 and started operating in 1842. It was housed in the building of the Xaireti brothers in Sofokleous street as a rental. Then it moved at Aiolou Street.	 **Figure 4b: National Bank of Greece**
 Figure 5a: Ludovico's (Ludwig) Square	The Loudovikos Square known today as National Resistance Square, commonly known as Kotzias Square. It is a central square of Athens and is enclosed by Athinas, Kratinou, Aiolou and Eupolidos streets.	 **Figure 5b: Ludovico's (Ludwig) Square**

Stage 5.3 Character construction

Existing character models were utilized and had been modified according to the dress code of the epoch, as presented below. The gamers will have the opportunity to gain an insight into the traditional costumes and cultural characteristics of the period and realize that 42 years after the revolution of 1821, the Greeks continued to wear fustanella.

Bandit - “Kyriakos” - Voice Assistant		Consultant
Rival Tribes		
	Highlander(Damage 5)	Lowlander(Damage 5)
Guards		
	Normal Guard (Damage 7.5)	Elite Guard(Damage 10)

Dimitrios Voulgaris

Politician from the island of Hydra

Chief of Lowlanders

consultant

Stage 5.3.1 Assumptions

1. The Loudovikos Square has been modified, based on a later redesign to make the level environment more attractive to the gamers.

2. In 1863 the building of the building of hotel "Great Britain" was smaller (a wing missed).

3. Boulgaris wore Ottoman clothes as Greek leaders-politicians did in the Ottoman Empire. But his character in the game is presented in a fez in an Ottoman style but with a fustanella. This mixture of styles was selected to emphasize the Greek identity of Boulgaris. The ottoman style was also chosen according to the material picture.

Stage 6 Evaluation and Presentation

Evaluation of the game by a jury.

Online Presentations of Prize-winning Digital Projects. (https://classroom.onassis.org/mod/page/view.php?id=1516)

4.1 Technological Equipment

The school organized a room-place suitable for students' work in purpose to work without distractions. For this purpose, the Municipality of Agioi Anargyroi - Kamatero donated two computers with features to manage multimedia applications with the following characteristics:

- C.P.U. : Intel Core i5 8500 3.00 GHz
- R.A.M.: 16.0 GB Dual Channel DDR4 1063 MHz
- MOTHERBOARD: DELL inc. 0654dc
- GRAPHICS: INTEL HD GRAPHICS 630

SOFTWARE

The game was developed on the Roblox platform mainly because it can be accessible to everyone (Roblox is a game that everyone plays, even primary school students). Secondly, it is a familiar platform to students participating in the project that could edit the game wirelessly and cooperate simultaneously. The creation of the imaginary world was developed on the Roblox studio platform through a student's account. For the needs of ECGBL - 17th European Conference on Games-based Learning of 5-6 Oct. 2023, Enschede, Netherlands, the game has been moved to a school's account, its graphics have been upgraded, new features and difficulty levels have been added, and it is currently available in English version.

Other software used:

- KineMaster - Video editing
- Photoshop - photo editing
- Sound recording by mobile & FL Studio
- PowerPoint Office 11 for the presentation of the project to real audience.

4.2 3D Video Game Development

Since our imaginary digital world was completed through the Roblox studio platform, the next step was to proceed to the programming. The coding language was "Lua" which is provided by Roblox platform. The students had to develop the character coding (movements, interactions), the character statistics and their upgrades, the collection system for the map pieces and items, recording narration, the voice coordination with the character, the integration of music, and synchronization of narration where the significant functions needed to be implemented.

5. Conclusions

At the beginning of the project, educators and students encountered various difficulties regarding the collaboration between participants and time shortages due to parallel educational responsibilities. Despite these obstacles, the Vocational School of Kamatero participated in the Onassis Competition "Hack the Map: Imaginary Worlds" and won the first award. This distinction filled not only the participants but all the school members with pride and joy. The social media shares were well received, and the school's prestige was enhanced in the local community. After this project, the relationship between the students was evaluated. Their collaboration capacity improved, and they became more eager to be involved in new tasks (Qian:2016); and they cultivated their computational thinking (Αλτάνης: 2019). They learned about a neglected historical period, all characteristic of

the Greek past. Surprisingly, the pupils realized that many elements of Greek folk culture, like bandits or the dressing, were maintained the same forty years after the Independence War, a period well-known due to national celebrations. At last, they understood how to study a map to recognize historical paths and estimate the monuments of the Capital they usually visit.

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Abbreviations

NGB: National Bank of Greece

HA/NGB: Historical Archives of National Bank of Greece

HHN: History of the Hellenic Nation

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Treatment Strategies for Different Types of Teacher Burnout Ä Barry A. Farber Teachers College, Columbia Universit

Design and Development of a Gamified Tutorial for iVR Serious Games

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Abstract: Serious games, including immersive Virtual Reality (iVR) experiences, can be challenging for players due to their unfamiliar control systems and mechanics. This study focuses on designing a gamified tutorial for iVR serious games that not only teaches iVR interactions but also enhances user enjoyment and engagement. The tutorial consists of progressively challenging mini-games that adapt to the user's performance. Tips and recommendations are provided through a robot avatar if users struggle or make mistakes. An optional narrative is included to enhance user engagement, but it is not mandatory for the iVR experience. Gamification elements, such as point collection and progress updates, are incorporated into the tutorial. It can be played independently or as an introduction to iVR serious games. The goal is to use gamification principles to maintain user engagement and flow while enhancing the learning experience in the virtual world.

Keywords: Tutorial, Virtual reality, Gamification, Serious games, Video games

1. Introduction

Since their inception, video games have gained popularity as a complementary tool for educators to enhance their teaching. Several studies have supported the notion that video games can facilitate learning and increase student engagement with the lessons (Hamari *et al.*, 2016). However, the mental processes involved in learning through video games are complex, and designers must consider various factors when creating both the game and the learning experience. Recent literature suggests that the novelty of a game, including surprising events, is what engages players (Huang, Jasin and Manchanda, 2019). Introducing a new tool into a classroom's routine can excite and intrigue students, but this novelty effect can have negative effects on the assessment of the learning experience's effectiveness (Huang, 2020). To address this, tutorials have been a part of video games since their early days, and their purpose is to familiarize users with the game's environment, mechanics, and controls. Tutorials can take various forms, such as physical instruction manuals, special levels, or pop-ups (White, 2014). However, not all tutorials are suitable for all players, as different games require different types of tutorials based on the player's skill and experience level. Tutorials can be implemented in various forms, such as audio guides, pop-ups, or non-playable characters (NPCs), but designers must carefully consider the game's type, player type, context, time, and instructions to optimize the learning experience.

In the realm of video games, the use of immersive Virtual Reality (iVR) technology is gaining popularity, as are serious games. iVR allows users to enter a virtual environment where interactions feel more natural compared to using a traditional console controller. Additionally, iVR has been found to enhance learning, as some studies have demonstrated (Checa, Miguel-Alonso and Bustillo, 2021). However, compared to non-iVR video games, the novelty effect is more likely to occur in iVR due to its newness and unfamiliarity among players. Thus, the inclusion of a tutorial is of paramount importance, as previously examined in research (Miguel-Alonso *et al.*, 2023). Tutorials not only teach users how to utilize the controllers, interact with objects, and comprehend the mechanics of the iVR video game, but also enable users to become acquainted with the iVR environment.

This study is focused on the design and development of a gamified tutorial for an iVR serious game. Previous research has highlighted the positive effects of gamification on skill acquisition, creativity, critical thinking (Najjar and Salhab, 2022), motivation, performance (Nor, Sunar and Kapi, 2020), learning outcomes (Alptekin and Temmen, 2020), and training results (Vargas-Macías, Rodríguez-Hernández and Sánchez-Saenz, 2020). In order to include gamification in the tutorial, various aspects must be considered, as outlined Trujillo-Espinoza *et al.*'s research (2021), including intuition, clarity, familiarization, and the use of interfaces to improve training performance.

However, the application of gamification in iVR tutorials has not been extensively researched (Howard, Gutworth and Jacobs, 2021). The primary goal of the proposed iVR gamified tutorial is to teach users how to

interact in the iVR environment and familiarize them with its workings. Moreover, the tutorial aims to be general-purpose to maximize its utility across various applications. To keep the tutorial engaging and prevent boredom, a storyline is incorporated (Kern *et al.*, 2019): users are guided through the tutorial by a robot that must escape a circus scenario. To accomplish this, users must complete various levels consisting of mini-games, while simultaneously learning the interactions and becoming familiar with the environment. The levels are increasingly difficult to enhance motivation (Škola, Tinková and Liarokapis, 2019), and they can be replayed as desired, but are not mandatory to achieve the robot's freedom and progress to the next application. The gamification system rewards or punishes users based on their success or failure, with points awarded or deducted, and special rewards granted for certain accomplishments. To improve skill acquisition, knowledge acquisition, and performance outcomes, various theories and literature are applied, including the Cognitive Theory of Multimedia Learning (Mayer, 2014), Gamified Learning Theory (Landers, 2014), Flow Theory (Csikszentmihalyi, 1991), and the book "Learn to Play: Designing Tutorials for Video Games" by White (2014).

2. Related Work

Several studies have emphasized the importance of tutorials for video games. Cao and Liu (2022) highlighted the significance of tutorials in teaching the mechanics of video games and increasing player engagement. Similarly, Shannon *et al.* (2013) demonstrated that tutorials in serious games optimize performance and knowledge gain and emphasized the need to properly design tutorials for serious games. Also, White (2014) contributed to this idea, adding that tutorials should be integrated into the storyline. To accomplish this, White recommended using minimal visual instructions accompanied by sound cues that complement the visuals. Both should be presented at the appropriate time and provide clear information. However, excessive guidance, redundant information, and presenting information at inappropriate times are not advisable.

In addition, White emphasized the significance of motivation in learning complex actions to avoid boredom. To enhance motivation, he explained the Operant Conditioning, which includes two effective methods of motivation through immediate feedback: providing positive reinforcements and removing constraints as rewards. Furthermore, the difficulty level should increase with the player's exposure time to the video game to maintain high motivation and help them acquire skills and experience. This will also increase their interest, leading to longer gameplay. Therefore, unnecessary repetitions in instructions should be avoided as they may decrease the sense of learning. White explained three ways of presenting instructions:

Cognitive apprenticeship, where a master model demonstrates how to perform an action as instructed to the player.

Just-in-time instruction, where an instruction appears when the player is frustrated and needs help.

Instructional scaffolding, where the player's skills and performance are continuously assessed, and instructions are provided as needed, particularly for advanced players who may not require much guidance.

Learning design principles were analyzed and explained by White in the field of tutorials. Firstly, he explained the way to achieve the same level of skills among all players. The principles considered to achieve this objective in the proposed iVR gamified tutorial are reducing complex mechanics, allowing skilled players to move as quickly as possible, and supporting learning by providing immediate feedback. Secondly, White emphasized that success should always be rewarded, and punishment given rapidly. For the proposed tutorial, these principles are applied by rewarding players immediately (and generously) even for their epic actions. In addition, the cognitive theory of multimedia learning established by Mayer (2014) was also followed to improve learning and avoid distraction. The most relevant principles for the design of the proposed iVR tutorial are: multimedia to combine visual and audio cues; coherence and redundancy to avoid saturation and distraction; segmenting to present tasks as simpler; contiguity to improve understanding by presenting information through close sources.

In the context of serious games for education, Bahrin, Sunar and Azman (2022) distinguished between gamification and game-based learning, emphasizing that serious games simulate real-life situations in which players learn something. Also, they proposed including the Gamified Learning Theory and the Flow Theory to enhance learning outcomes. In their research, Landers, Armstrong and Collmus (2017) explained the Gamified Learning Theory and its two ways in which gamification affects learning. The first is as a mediator, where behavior changes induced by gamification directly impact learning outcomes. The second is as a moderator, where gamification modifies learners' mood and improves learning efficiency. Additionally, they suggested that gamification should not hinder learning, but instead should be felt as an option and comply with the game's rules. In relation to learning, it is considered the state of flow, which not only requires concentration,

but also the user to feel interested and enjoy the iVR experience. Furthermore, flow affects learning outcomes. According to Csikszentmihalyi's Flow Theory (1991), learning is composed of three channels: boredom, flow, and frustration. When skill and challenge are in balance, the learner is in the flow state, which is the optimum one for learning. In contrast, when skill is too high, boredom occurs, and when the skill is not enough to overcome the challenge, the learner will be in a frustration state. The objective of the iVR gamified tutorial is to maintain the learner in the flow state by applying and adapting its dimensions. These are: presenting clear goals to help avoid distraction; giving immediate feedback to increase confident and improve learning and performance outcomes; skill-challenge equilibrium to avoid boredom and frustration; sense of control to increase confidence; action-awareness to become the player involved in the game; high concentration to help avoid distraction; loss of self-consciousness to increase the involvement; rewarding activity to increase motivation; temporal distortion to increase involvement.

3. Design and Development

For the design of the proposed iVR gamified tutorial, the previously explained background research was utilized. As a first step, the Gamified Learning Theory was considered to provide players with freedom and to give meaning to their actions. Additionally, the tutorial is not limited by a specific objective, allowing for players to surpass it. As the tutorial is an iVR experience, interactions were designed to be as natural as possible, resembling interactions that occur in the real world.

In the design of the proposed iVR gamified tutorial, Flow Theory was applied by considering the three dimensions that are most relevant for tutorials. Firstly, clear goals were established as one of the main objectives of the tutorial, as having a clear task reduces distraction and frustration for users. Secondly, immediate feedback was provided to the players in the form of rewards for successes or failures, which enhances their knowledge gains. Lastly, the skill-challenge equilibrium was considered by proposing tasks that increase in difficulty and can be repeated as many times as the user wishes to maintain engagement and motivation while facilitating learning and skill acquisition.

Finally, as proposed by White, the iVR tutorial is not a separate level, but rather a series of mini-games that allow for exploratory learning on how to interact with objects and the environment. However, for skilled players, instructions are kept to a minimum, adapting to the learning pace of individual users. To achieve this, the tutorial combines just-in-time instructions when the player is frustrated or unsure of what to do, and instructional scaffolding to eliminate unnecessary instructions as the player progresses. Additionally, cognitive apprenticeship is included to optimize learning. The tutorial is designed with easy-to-understand interactions that allow players to learn at their own pace and achieve the same level of skill. Immediate feedback is provided not only for success, but also for failure and exceptional performances. Finally, dynamism is incorporated to adjust the complexity of the tutorial to the individual player.

Based on the literature review, the proposed iVR tutorial is situated in a circus environment, as it is shown in Figure 1. This location was chosen to convey to users the idea of a fun and playful activity. The circus is a familiar and safe setting, as it is enclosed and has predefined rules, which are conveyed through the tutorial's appearance, such as calming colors and rounded forms. Thus, users will know from their first contact that the activities will be fun and not stressful. The circus is designed with a central circular area and stands to close the stage, which limits the user's movements and reduces production time and costs. To enhance the environment and prevent the feeling of emptiness, certain items are included in the environment, but user interaction is not permitted to avoid errors. The tutorial begins by allowing users to freely familiarize themselves with the environment, and they can start playing when they are ready. The main purpose of this non-interactive introductory level is to enable users to experiment with the iVR controllers, become comfortable with them, and visually explore the space. If users take too long to start playing, pop-ups will appear to provide tips on what to do.

Figure 1: Virtual Circus scenario during the development phase

In addition, users can access more information by accessing the menu. The menu screen includes the controllers showing the function of each button, which is considered by White as an appropriate way of implementing a tutorial. This strategy of explaining the possible interactions does not interfere with advanced users, as they do not need this information. Additionally, it complies with Mayer's multimedia principle, pre-training principle, and coherence principle. If users do not know what to do, they may randomly press buttons hoping to succeed and continue playing. At a certain point, they will access the menu and discover tips on the controllers that may be helpful to them. The rest of the interface appears when users take too long to perform a specific task in which they are involved. A pop-up appears, giving them some tips according to the just-in-time instructions explained by White. Also, as a first contact with the task, a robot avatar shows the users how to perform it, following the cognitive apprenticeship method also explained by White. Furthermore, the instructions disappear as users progress, and if they do not know how to continue at some point, tips appear as pop-ups. These tips shown as pop-ups follow Mayer's theory by displaying information at the moment when needed (contiguity principle), avoiding repetition of information (redundancy principle), and having a simple design to avoid distractions (coherence principle), as it is shown in Figure 2.

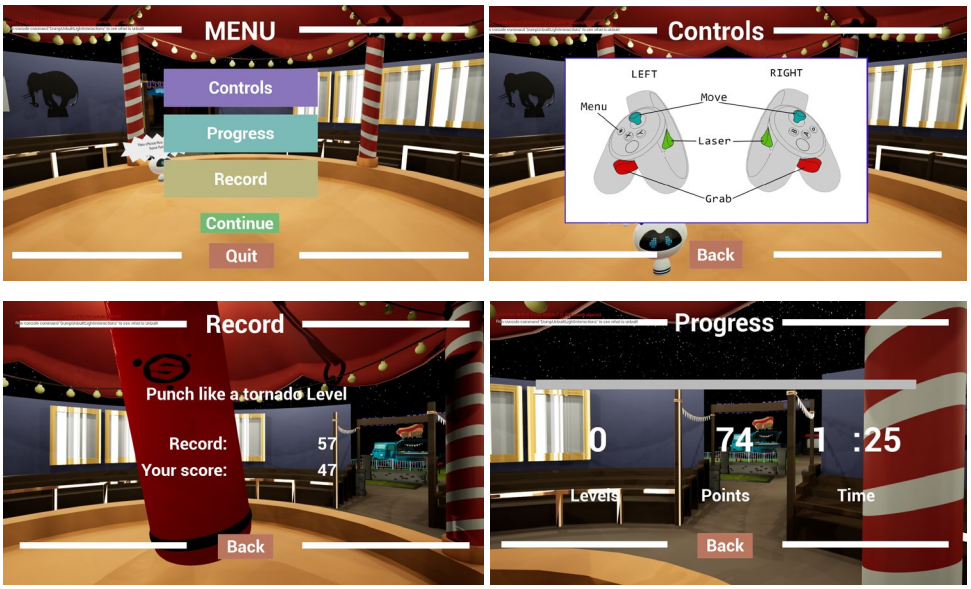

Figure 2: Pause Menu, controls, record, and progress screens

The levels of the iVR tutorial are situated in the circus scenario and consist of games or objects that are easily recognizable. These levels involve basic iVR interactions, and the robot avatar provides instructions and allows the user to choose which level to play. The difficulty level increases gradually, striking a balance between challenge and skill, and adapts to the user's level of proficiency (segmenting principle of Mayer's theory). Moreover, users can repeat levels as many times as they like. A reward system and feedback mechanism are in place throughout gameplay, with users earning points for success and losing them for failure. If users

experience repeated failures, pop-ups with tips or the robot will appear to offer advice on how to improve. The system is designed to be simple, as recommended by Chittaro and Buttussi (2019), and does not require further complexity. The levels and interactions proposed in the iVR gamified tutorial are as follows (see Figure 3):

Introduction: This initial part allows users to explore the environment and get familiar with the virtual world. A magic cabin will appear to insert the ticket of the chosen level to start.

Strike the Toys: In this level, users will learn and practice the interaction of grabbing and throwing objects. Users will be allowed to throw balls and strike toys that are positioned at different heights and angles. More points will be awarded for striking the more difficult toys, and users will lose points if they fail to gain any points.

Punch Like a Tornado: Users have to punch a boxing bag as fast as possible within a given time frame. The more hits they get, the more points they earn. The best score among users is recorded and they can surpass it and being rewarded with new objects to punch. This level helps users get familiar with the available space for playing and interacting with the environment.

Slot-Road: In this level, the user has to master the grab interaction by pressing the button of the controller to make a car move and not pressing the button or almost not pressing it to take the curves. The user has to complete the whole laps perfectly to gain points.

Dress the Potato Up: Users will be rewarded with points and the ability to create special effects for the potato character if they dress it up completely by attaching a piece of clothing of each type. This level helps users master their abilities of grabbing and attaching items.

Figure 3: Levels of Virtual Circus: Strike the Toys, Punch Like a Tornado, Slot-Road, and Dress the Potato Up

The techniques employed to indicate players' progress may appear redundant, but this repetition contributes to the engagement of the experience, as evidenced by Krishnamurthy *et al.*'s research (2022). These techniques consist of displaying earned or deducted points and a progress bar indicating the total points required to free the robot. To prevent distractions during the experience, both elements are only displayed in the menu. Additionally, the high score record is displayed in the Punch like a tornado and menu screen, as well as the completed levels.

The incorporation of a robot avatar in the proposed iVR gamified tutorial serves to advance the storyline, which centers around the player's objective of accumulating as many points as possible to secure the robot's release from the circus. While it is possible for players to complete the tutorial without finishing the storyline, doing so will prevent the robot from being freed. As White has argued, the tutorial is not obligatory. Instead, it is intended to prepare users for subsequent serious games while also enhancing learning and performance by minimizing the novelty effect, which can impede learning outcomes. The tutorial's storyline establishes a clear objective for the user, which is further broken down into smaller objectives such as gaining a specific number of points and successfully completing the levels. The tutorial's flow is balanced, with the storyline and the

user's skill level matching the proposed challenge. Additionally, the robot provides supplementary information to the users by speaking with them. This aligns with Mayer's theory's redundancy and multimedia principles.

In summary, the design of the proposed iVR gamified tutorial incorporates gamification elements, such as a system of rewards and punishments, a storyline that provides clear objectives and increases engagement, while also achieving the main objective of a tutorial, which is to teach users how to interact with objects and become familiar with the virtual environment.

The development of the proposed iVR tutorial consisted of two stages: modeling and texturizing, and programming. Blender version 3.4 was used for modeling, during which the scenario and interactive objects were created. During the texturizing phase, the modeled elements underwent the application of colors and textures. Some objects lacked proper image textures to save resources on computer memory and to optimize the project's lighting. These objects were those that were placed far from the user's proximity and their visual quality was not critical for user experience. As an example, the steps that surround the scenario were not accessible to users, hence their visual quality was sufficient without impeding the rendering process of the iVR tutorial. Both Blender version 3.3 and Adobe Substance were employed for the creation and application of textures. Finally, the programming phase was implemented using Unreal Engine 5.1. The engine was selected due to its user-friendly node-based programming system, as well as its reputation for creating photorealistic environments and ease of use. These advantages allowed for the programming of the designed interactions while maintaining the established visual quality, and ultimately saved time and development costs.

4. Results and Conclusions

The proposed iVR gamified tutorial has been successfully designed and developed based on the principles of the Gamified Learning Theory, Flow Theory, and the Cognitive Theory of Multimedia Learning of Mayer. Furthermore, the design and development process has been carried out in accordance with White's proposal for creating an effective tutorial. The tutorial includes gamification elements, such as a reward and punishment system, a storyline to increase engagement, and clear objectives for the user.

The proposed iVR tutorial is intended for general use and includes basic interactions commonly used in iVR applications. Users can not only learn these interactions but also master them as the difficulty level increases. One of the key features of the tutorial is its incorporation of gamification elements to enhance engagement, performance, and learning outcomes. The application functions as a tutorial and serves as an introduction to serious games or can even be considered an independent iVR game due to its storyline and playability. The mini-games that form the storyline are equivalent to levels, each with unique objectives and rules. Users can gain points or rewards upon success, while failure results in point deduction or other punishments. A robot avatar accompanies the user to provide guidance, adapting to their progress. Tips and recommendations are only provided when users struggle or take too long to complete a task, ensuring that the displayed information is clear, simple, and coherent without being redundant or distracting.

As future lines, artificial intelligence will be integrated into the proposed iVR gamified tutorial. This technology will enable the tutorial to analyze users' performance and adapt to their level of competence, thereby enhancing the training process. Furthermore, users' personalities will be studied prior to the experience in order to tailor the tutorial to their individual learning styles and preferences. This will help to optimize their learning outcomes and ensure that the tutorial is effective for all users. Additionally, avatars will be created for the players to enhance their sense of embodiment and immersion in the virtual environment.

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Could the Technology for Adaptive Learning Systems Come out of GBL?

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Abstract: Games based learning (GBL) has a related field that it can draw upon: intelligent tutoring systems (ITS). A common concern in both fields is *adaptivity*, whereby the system can automatically adapt to the user. In order to support this adaptation, an ITS will generally include a user model and may also have a formal domain model. Work in this area started optimistically some years ago, but seems to have either lost some of that initial enthusiasm or been diverted into other directions. We scan recent ITS literature to help consider why this might be, and suggest how GBL may be the field best placed to take the work forward again. Learner models have long been seen as useful for adaptive learning systems. They include information about the learner which allows the system to adapt the course of learning materials and exercises to the learner's particular characteristics. In order to achieve a good quality of adaptation to the user, a detailed model of the required domain knowledge is typically added. The user and domain models then have to be brought together to lay out a course of exercises for the learner to do, and to track progress as the knowledge is learned. It's an attractive research programme, but recent work has moved to new issues, such as MOOCs. The reasons for that are partly opportunistic and economical, but also suggest a deeper problem with the research programme. It is a costly task to develop a domain model, and a suitable learner model that can take advantage of it. We suggest that GBL is in a good position to push through this cost barrier, because much of the effort is already implicitly involved in the game design process, which typically has to be more rigorously planned out in order to make the game a good one. One might thus expect the next breakthroughs in adaptive learning systems to come from GBL. We further argue that the advantages to research, offered by the ITS framework, are also potentially beneficial to the way we teach the subject of GBL to our students on game development courses.

Keywords: GBL, ITS, Learner model, Domain model, Teaching GBL

1. Introduction

The first international conference on Intelligent Tutoring Systems (ITS) was in 1988 in Montreal (Gauthier et al., 2000), and it now runs annually. The field of ITS is related to GBL (games based learning), although it emerged directly from Artificial Intelligence in Education (AIED). It aims to make tutoring systems intelligent and adaptive, rather than game-like. There are shared interests however, and such related fields should attend to, and learn from each other.

Here we first describe how the field of ITS emerged from earlier work in cognitive science, that promised a healthy future in learning support systems. Then we introduce the main concepts and terms for this emergent field, to be explored in the rest of the paper.

1.1 A Leading Example of ITS

Emerging from cognitive science in the 1980s, some of the most promising tutoring systems came from researchers at Carnegie Mellon University, led by John Anderson. The specific theory of human cognition deployed was Anderson's ACT-R model (Anderson, 1993, 1996). They reviewed their work, which they called 'cognitive tutors', to find that they usually offered significant achievement gains, in that students learned faster (Anderson et al., 1995). The desired knowledge state was represented in the system as a set of *production rules*, which is a concept from AI that can be thought of as *if-then* rules from situation to action.

Their method was to take an expertly designed curriculum in the domain, and set a sequence of problems for the student to solve. The ideal solution for each problem was then encoded into production rules, and all was packaged into a tutor system with an appropriate interface. All the main parts of the system can be seen as fitting into the more general framework that is described below.

1.2 Concepts to Come From ITS to GBL

As said, the fields of ITS and GBL should be able to learn from each other, by sharing concepts. One such idea that could be taken over is that of the user model (UM). We show below how this and other important

concepts in ITS may be brought into GBL with advantage. Let us first introduce some acronyms for these concepts that show how ITS and GBL fields relate to each other in formal terms.

An important framework or architecture for an ITS includes a user model of the learner, which is thus called the LM (learner model). Elementary sorts of information could include the learner's background or entry skill levels, learning goals, or learning styles. Often, it also includes a model for the knowledge domain, that the user is supposed to learn from the system. This DM (domain model) is analogous to a world model in a GBL system (or serious game, SG). It is unusual in GBL to make these models of the learner or domain explicitly *formal*, however: rather the knowledge they would contain and structure is spread implicitly throughout the game software. On the other hand, the field of ITS has often tried to give such formal models a central role, with some success; and this inspires us to explore how such an approach might similarly benefit the field of GBL.

In the following, we describe how formal models of the learner and domain are put into a framework that has organised many systems in the field of ITS, and how successful it has been. The successes have been limited in some ways though, or disappointing; and we look at the publications of the leading ITS conference series to see how the attention has shifted to other research directions, such as recommender systems, that offer other advantages. We suggest some economic and other practical reasons why this shift in the field has occurred.

2. A Modelling Framework for ITS

Since decades, ITS has tried to build upon the use of models, or components, when making systems according to a general framework. In 2010 the conference made a milestone assessment of the history and status of the field's efforts in this direction (Nkambou et al., 2010). Their classic view of what the chief models should be is pictured in Figure 1, and still organises the field today.

In this view, the models are those components of the software architecture that contain knowledge to support reasoning. They also happen to embody the components or agents of knowledge that teachers already intuitively identify.

The student is depicted at a computer, wanting to learn the subject matter, which in the example is about space travel. She has some notion about what she is going to learn, but it is not yet a full or accurate picture. The system is intended to give her more extensive knowledge about the domain, such as the design of the International Space Station in the example.

The architecture identifies the knowledge that is to be taught to the student as the **domain model** (DM), which adds structure to the information in order to teach it more methodically. In the example a typical notion of structure is illustrated as a *curriculum* of topics or chapters with logical dependencies between them, such as a student will commonly find at the beginning of a textbook. In the example the topics numbered 3 and 4 may be learned in either order, but only after topic number 2.

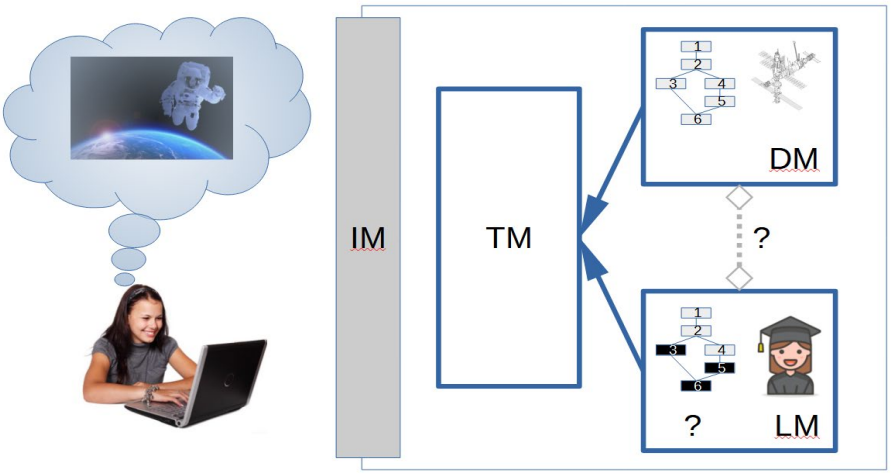

Figure 1: A full ITS framework, showing all the main components of an ITS (intelligent tutoring system). They are the IM (interface model), TM (tutor model), DM (domain model), and LM (learner model)

The student herself is also modelled inside the system, including her current state of knowledge and perhaps other attributes, as the **learner model** (LM), which may also be known as the student model. The picture suggests that she has so far learned some parts of the curriculum (1, 2 and 4), but has not yet gone through the later parts (3, 5 and 6).

Those two models in the architecture are the most obvious and common, and many systems might have one or the other or both of them. In practice, researchers typically have a focus on one main issue, and develop their systems and present their work with an emphasis on the most relevant model in the architecture. The other parts of the architecture are then not identified explicitly, and are often not even identified as separate components in the software. In such cases the functions of the missing modules are either trivial, or still performed in some fashion by the ITS, but only implicitly, as if threaded throughout the code.

A fuller implementation of the architecture would have the other two modules as well, including the **tutor model** (TM) and the **interface model** (IM). These embody the knowledge of how to teach the subject (TM), and how to present each part of the lesson to the student and sense the mental state (IM). In early systems these were combined into a single metaphor of the teacher, to be personified as an artificial agent acting as a person. However, in Figure 1 the tutor is not often represented as a person, but is kept rather abstract. This is because researchers found that students often preferred to see the system as a tool, more like other standard types of computer system. The tutor model thus includes the teaching style or method that a real teacher might deploy, to inform the student or set tasks according to the preferred educational theory.

The framework shown in Figure 1 gives a good general view of how research in ITS can be organised, but it is not definitive. It could be extended in useful ways, and in particular we shall propose an extension of the domain model to world model, for the purposes of GBL.

Before we get to GBL however, let us first see how the framework and its various models have fared over the years. One might expect that the early promise of the approach would lead to accelerated interest, a growing consensus, and greater uptake. That is not what we find in the literature, however.

3. Partial Success of the ITS Framework

It may seem odd that an approach to ITS that was already promising more than thirty years ago has not yet achieved wide recognition, despite its early successes. We suggest some reasons why that may be, below, but first conduct a bibliometric analysis to see how the interest in this modelling approach has developed over time in the field.

We examine the papers from all conferences of ITS, from the year 2000, to compare with later ECGBL conferences (from 2010), to see if the concepts have moved across from one field to the other; from ITS into GBL.

On initial inspection, we noticed that the different sorts of models from the framework (the SM, DM, TM, and IM) are not equally popular. Altogether over the period, there were 182 papers mentioning student models (or learner model or user model). In fact the most common by far are the student and domain models; whereas the other two are comparatively rare, with only one of each occurring in ITS papers as their main focus (Kumar et al., 2014; Raad & Causse, 2002) The first observation we make is thus the uneven distribution of papers about different parts of the framework, and this raises the first question.

One may wonder why most papers only include or refer to one or two models from the whole framework; and can they even be said to fit into the framework if they do not explicitly include all the parts? Firstly, researchers have their own focus of interest, and that focus typically crystallises into the relevant model. Secondly, the framework can still apply even if only one of the models is explicitly involved, as long as we grant that the functions of all the models may still be fulfilled by the system. The function of a tutor model (TM), for example, may still be performed by the system even if it has no such model or code explicitly in its design. This may be because the function is relatively small or trivial; or if it is more significant it may still be left implicit, with the functionality threaded throughout the code.

3.1 Models Have Lost Popularity in ITS

As well as the uneven attention given to different parts of the framework in the field of ITS, there is an interesting change in attention *over time*. We first noticed that papers about learner models appeared to be more common in the early years, of say 2000-2010, with a peak around the year 2006.

To confirm this, we performed a bibliometric analysis by searching for keywords and terms in all the papers: our own collected database for all the ITS papers from the year 2000, and the online ProQuest database for the ECGBL papers from 2010. We used synonyms as alternatives because researchers often use different words but they mean the same general concept. For the concept of the **learner model** (LM) we also searched the terms 'student model' and 'user model'. Table 1 shows the occurrences in ITS papers across all the years to 2022.

Table 1: Occurrence of learner model concept in ITS papers (LM). Conferences were every two years until 2018, and then became annual, so years are combined. Total number of papers per year, published in the proceedings, are in the bottom row.

\ Years Keyword	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019-20	2021-22
Learner	2	4	3	13	8	6	5	3	1	1	3	0
Student	22	13	11	8	6	6	8	10	3	2	3	2
User	6	3	5	1	6	0	1	1	0	0	1	1
SUM LM	33	24	23	25	23	13	16	16	6	3	7	3
Totals	92	117	127	113	120	159	134	110	52	73	113	96

We can see that the synonyms change over time, as one might expect. The term 'user model' was used more in the earlier years, for example, but then got slowly replaced by the more specific terms gaining acceptance, namely 'student model' and 'learner model'. This reflects the establishment of the general framework over time.

Total usage of these terms or concepts, however, first grows quite nicely, but then declines over the years. This can be seen more clearly in the chart of the data, Figure 2, for the concept of learner model (LM).

The chart shows that the concept of learner model was very popular in the year 2000, occurring in about a third of all papers that year. However the concept became less popular over time, dwindling down to less than 5% nowadays.

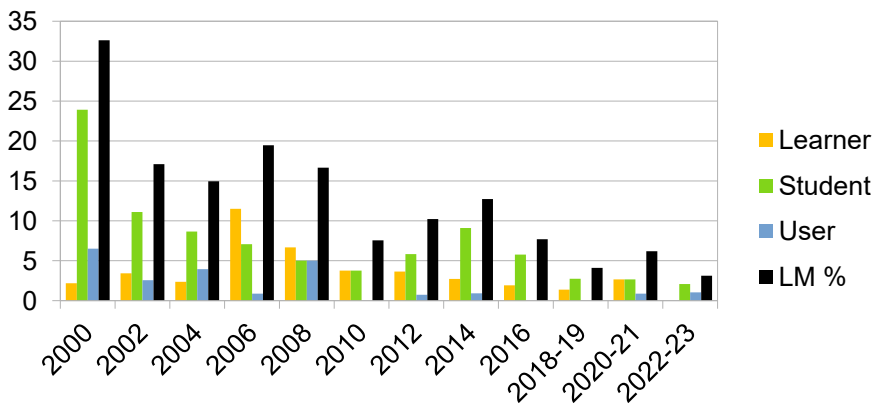

Figure 2: Decline of interest in the concept of learner model (LM) over time. Black bars show the sum for all the alternative keywords. All bars show percentage of papers for that year

The learner model is the most popular model of the framework, and the domain model is next. A similar pattern occurs for the concept of knowledge or domain model (DM), with interest rising to 10% in the year 2008 and then falling away again.

Research interests in a field may change over time for a variety of reasons. One possibility that emerges here is that interests have switched to a new, and more fashionable direction, such as MOOCs (Massive Open Online Course), or 'recommendation systems'. These terms have indeed become more common, generally as well as in the ITS literature; and in fact taken together they make an appearance in 2016 and rise to the levels that DM itself had in 2000-2008. To that extent then we can say that the decline of the ITS framework and its models is partly due to getting supplanted by the latest new fashion.

The decline may signify a deeper malaise, however. After all, MOOCs and recommendation systems do have some advantages, both in feasibility and economics. The MOOC is a course that can easily be scaled up to massive numbers of students with only a technical need of more servers. Recommendation systems are a commercially successful AI technique for recommending products to buyers online, by simple rules based on their previous purchases. They also have a therefore, in that they do not reliably fit well to an individual. Thus we find that MOOCs have a recognised problem of students dropping out, and researchers are still not clear about exactly why that is (Alamri et al., 2019, 2020). In future the ITS approach may come back, as a way to tackle those problems; but first it will need to overcome its own problems that have led to the drop in interest we have found from our analysis above.

3.2 Barriers to ITS

We have demonstrated a drop in research activity, within ITS, that follows the modelling framework set out above. Researchers in the field might not have noticed that drop as such; but some have noted that the field of ITS as a whole has struggled to overcome some barriers (Nye, 2014). Curiously their conclusions are consistent with our own findings from the literature analysis above. They note that barriers related to students have received the most attention, but that other barriers related to teachers and schools have received less. We consider to be consistent with the prevalence of domain and learner models, and the scarcity in the literature of tutor and interface models.

Reviewing the technicalities involved in building the first successful tutoring systems, we can readily understand where some of the difficulties lie. To build a system like those described in section 1.1 above, for example, needs a domain expert to draw up the curriculum, and a specialist to encode the desired knowledge skills into production rules. The specialist needs to be an expert in that type of AI, essentially; an ordinary programmer will not do. The interface model may also need to be modified significantly to suit the school and students. That is a lot of varied expertise that is needed; and even then the task demands time to build and presumably test the system.

4. GBL can use the Framework

Let us first note that gamification has been attractive to the field of ITS because they recognise that lack of student motivation is one key reason for the massive dropout rate in MOOC systems. A few AIEd and ITS researchers therefore add game-like elements into their MOOC courses (Maalejl et al., 2015). However, game design is yet another technical and design skill that would overload the development of such systems more than it is already.

The field of GBL should have better access to game design skills, and so we now explore the suggestion that it could import the framework ideas from ITS to put its own research programme on a more robust footing.

GBL researchers have often been developing along similar or parallel lines. Some have thought in terms of mental models of the learners or players; or have formalised the domain knowledge in order to clarify what they are aiming to teach at different stages of the game-play. However they have also done so without awareness of the parallel and more formally developed work in the field of ITS. This shows that the field of GBL shares the idea that this kind of development lies in a good direction; but also that it has less idea of the virtues of building a shared formalisation framework. We argue that the more formal ITS approach offers several advantages. Many different research projects that use the same formal framework can be more easily compared with each other, to give better measures of progress. Standard benchmarks can be applied to help evaluate research projects, both in performance, and in extent and depth of modelling achieved. The framework and models themselves could, and probably should, also develop. This would reflect the growing understanding of the field as the various micro-theories embedded within are developed, evaluated, and adopted; or discarded in favour of better ones.

As a reviewer of this paper helpfully suggested, we also agree that the field of GBL does need to focus more on cognitive absorption of knowledge, and not merely rely on the supposed attractiveness of games to motivate players. One good way to confront and surmount this issue, which is a kind of obstacle to progress in the field, would be to bring in the ITS approach.

Some papers in the ECGBL conference series have suggested that concepts from ITS would be helpful to make better GBL systems. For example Zapusek & Rugelj (2013) advocate that GBL can learn from ITS, in particular to make serious games more adaptive to the student's needs. Other authors recognise that there are big technical challenges in making a serious game, and propose an authoring environment to help do this (Tran et

al., 2010). That idea arose first in the field of ITS, and they also take over the notion of key components; although they are not exactly the same ones, and they use their own names for them instead of the standard terms that we have mentioned in this paper. While it is not necessary to change names for the concepts, we suggest that it can be a good idea to modify them to suit serious games.

4.1 GBL can Modify the Framework

The concepts of the models that have been identified, for the learner, tutor, domain and interface, are abstract enough to fit many applications. In the case of GBL however, some modifications are clearly needed. The most obvious one would be to change the name of the learner model (LM) to player model (PM). There is one paper from the ECGBL in 2015 that does include a "player model" (Callies et al., 2015).

Another change could typically be useful for the domain model (DM). That is, the domain (or subject material) of the game could be divided into two parts: the world model (WM) and the domain model (again). It is important that the information that the students are supposed to learn should be accurate and correct, and not confused with the fantasy material. This is why we divide the proper domain from the larger world model (WM) than encloses it.

4.2 Possible Advantages to GBL over ITS

The field of ITS has recognised the benefit of the framework, which is why it was proposed in the first place. Their regular researchers have demonstrated the effectiveness of systems based on the framework. However, as we have shown, there are also difficulties which are limiting progress in ITS. We make some observations here to support the notion that GBL research might be able to take the ideas further, due to peculiar advantages of the field.

The nature of interaction with video games is one likely advantage over the more conventional web, and other sorts of interface found in ITS. As we noted in section 1.1, a significant achievement of the first ITS tutor systems was credited to immediate, informative feedback. That happens to be something that most video games excel in!

One economic difficulty with ITS is that it has to make systems based on general infrastructure, like the internet, and associated technologies. If it needs more infrastructure or toolsets then it will have to build them itself.

On the other hand, GBL has access to game technology which comes from the commercial wing of the industry. This includes ecosystems of art assets and other game assets, many of them freely available for educational purposes. It similarly includes sophisticated game engines, platforms, and other auxiliary tools like those for game analytics, which can also be used as *learning analytics*. Such tools give an advantage in making good quality tutoring systems that can run on all platforms.

The games industry has other assets in its game worlds, such as characters for players (avatars) and non-player characters. Much can be done with those, as long as they can be shared affordably. The technology and game worlds may already simulate the regions and parts of the real world, and with high fidelity, which may be suitable as a base for serious games. There are softer resources potentially available as well, including skills of expert game designers, and protocols and other support for play-testing games in their later development stages.

4.3 What the ITS Framework Might Offer to GBL

Along with the prospective benefits, that the field of GBL could offer to the ITS framework, there would also be costs implied in adopting it comprehensively. There should therefore be attractions to the field in return. The framework should be able to help the cause of GBL just as it has already been seen to help ITS, in making tutor systems that teach more effectively. There are also software benefits in making a system out of components, as mentioned above.

We can speculate on further benefits if we consider what is generally the point of an architectural scheme that conceives a system as composed of components such as in the framework. Note that the components are not just any software unit; they are called *models* for good reason. The interface model (IM) for instance is a useful way to isolate all matters of direct interaction with the student (or player), so that the system can more easily be modified for other platforms or contexts. The other models, too, are convenient ways to identify different sources of expertise.

The domain model (DM) has its own domain or subject expert, while the tutor model (TM) naturally embodies the pedagogical philosophy. According to a survey of schoolteachers by Rocha et al (2018), one of the main problems they have with GBL is that they feel the games are *poorly designed*, pedagogically. One way to fix this problem could be to adhere to the framework and include an explicit tutor model (TM), thus allowing the pedagogical method to be modified more easily.

Models in science are often used to predict the outcomes of experiments, and they could also be used to make predictions in the game context. For example, the system might predict how the student or player will perform or react, and adjust the pace of the game accordingly. This allows the game to automatically alter the difficulty level, which is known in games as DDA (dynamic difficulty adjustment).

4.4 Advantages to Education of the Field

So far we mentioned advantages of the ITS approach to GBL as a research field, but it can also help us to educate the next generation of researchers and practitioners. Educational courses in GBL have many things in common, including basic motivation by means of playful interaction, and the use of popular examples of serious games to illustrate what can be achieved. However these courses are often organised along various different lines, according to the taste of the teachers. Just as the research field can be reorganised, such as along the ITS modelling framework suggested here; then in just such a parallel manner can educational courses be similarly organised. In that way, many of the suggested advantages of the framework mentioned above (at the start of this section) would also apply to GBL education.

5. Conclusion

We have conducted a bibliometric analysis of the literature from ITS and ECGBL to track research activity in the important framework concepts of learner and domain models, along with the less popular tutor and interface models. We have shown that the research interest started well and optimistically, but has fallen away since then. This has been partly due to a redirection of attention to other new topics, but also because the framework has run into difficulties and resistance in ITS. Ideas from the framework have been taken up by some researchers in GBL, or at least advocated; but they have not been widely adopted.

We argued that the ITS framework with its models could be used within GBL research to give a coherent structure both to individual systems and serious games, and to the field as a whole. Firstly the field benefits from a more advanced technical base, thanks to sharing infrastructure and other assets with the neighbouring commercial games industry. This gives GBL some advantages over the field of ITS. Secondly, the use of formal models within a serious game enables it effectively to make predictions and thus adapt to the student or player. This could lead to further lines of research like 'dynamic difficulty adjustment', and beyond. Thirdly, the models would allow knowledge sharing, to make game development more collaborative; not only by sharing software components, but also the pedagogical theories and the student models that can build up over time, and tested, and sometimes even benchmarked.

There are potential advantages also to using the framework in education, to structure courses in the GBL area. We are currently restructuring one of our own courses in serious games design, to take advantage of the framework. This is done in order to map out the strengths of current research that can be expressed in learner models, as well as to indicate where more research is needed, such as in better design of the cognitive / emotional interactions that should drive learning from the game-play in serious games.

The use of the framework may thus pay for itself in the end, by making individual serious games more adaptive, and intelligent; and also by organising and invigorating the research field of GBL, with stronger methodology.

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Enhancing Pre-Schoolers' Learning Motivation in *Jawi* Subject Through Game-Based Learning Application

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Abstract: Game-based learning applications are becoming increasingly popular as an effective means of enhancing student motivation to learn. *Jawi*, a subject often viewed as uninteresting by students, has decreased motivation to learn due to a lack of technology resources. To address this issue, the "*Dunia Jawi*" mobile application was developed as a game-based platform to improve preschoolers' motivation to learn *Jawi*. In this study, student motivation was measured based on the ARCS model, which consists of four components: attention, relevance, confidence, and satisfaction. The study involved a pre-experimental group of 32 preschoolers evaluated using the pretest-posttest design. The results found an increment in preschoolers' motivation, where the mean for the posttest (43.50) was higher than the mean for the pretest (31.47). The increment was statistically significant, indicating that the use of the "*Dunia Jawi*" mobile application led to a significant increase in motivation to learn *Jawi* among preschoolers. Moreover, each ARCS component showed an increment in attention, confidence, and satisfaction. The attention component refers to capturing students' interest and encouraging them to focus on the learning material. The confidence component refers to the student's belief in their ability to learn the material. The satisfaction component refers to the student's enjoyment of the learning experience. The results indicate that game-based learning applications, such as "*Dunia Jawi*," can enhance each component, thereby increasing student learning motivation. The relevance component, which deals with how the students view the value of the learning content, did not, however, experience any appreciable shift. The "*Dunia Jawi*" mobile application may not have had as much of an influence on this component as it could have because the preschoolers may not have seen the content as being applicable to their everyday lives. In conclusion, this study proves that game-based learning applications, coupled with the ARCS model, can enhance preschoolers' motivation to learn *Jawi*. The results demonstrate that the "*Dunia Jawi*" mobile application effectively increased preschoolers' motivation to learn *Jawi*, particularly in the attention, confidence, and satisfaction components. Future studies could explore ways to increase the learning material's relevance to further enhance preschoolers' motivation to learn.

Keywords: Mobile- game application, Learning motivation, ARCS Model, *Jawi* learning

1. Introduction

Jawi is a writing system used to write the Malay language using Arabic script. It is named after the Arabic word for "Java", as it is believed to have originated on the island of Java in Indonesia. The *Jawi* script was widely used in the Malay Archipelago before the introduction of the Latin alphabet by European colonizers. It is still used today in some parts of Southeast Asia, particularly in Malaysia, Brunei, and some parts of Indonesia. *Jawi* is a subject in the primary school curriculum in Malaysia. However, there has been an issue of the decline in student achievement in *Jawi* subjects, it was found that the factor in the occurrence of the situation is that students need to be provided with more reference resources to empower *Jawi* education. Unlike other subjects, the dumping of printed and digital reference resources has helped improve student performance.

Besides that, the teacher's delivery method during the teaching process is also a constraint for students in achieving understanding and satisfaction in the learning process. Thus, the decrease in student motivation in education is not a small matter. The need for reference sources is one of the main factors in this issue. The use of innovative teaching aids based on student needs is seen as an effective initiative in re-increasing student motivation in learning *Jawi* subjects. According to Keller (2010), learning motivation needs to be instilled in students as early as the introductory session and needs to be maintained to ensure that students can develop their own skills. To solve this issue, a game-based learning application is the best approach as a *Jawi* learning resource suitable for all ages, especially preschoolers. The applied game concept can make students have more fun when learning *Jawi*. In addition, the use of game applications can foster the concept of student-centered learning that can build confidence (Reynolds, Roberts, and Hauck, 2017) and foster a positive perception of *Jawi* education (Adly and Mardzelah, 2016).

2. Research Background

2.1 Student Motivation Problems in Jawi Learning

The decline of the *Jawi* learning skills is the beginning of the *Jawi* writing marginalization in the future and needs to be curbed as early as the preschool level (Yusoff, 2005). According to Wahab et al., (2017), the decline in *Jawi* mastery is linked to the problem of *Jawi* learning materials that do not attract students' interest. In addition, the results of a study by Mardhiyyah (2012) showed that most respondents often showed a bored reaction when the teacher used traditional method during *Jawi* learning session.

Various efforts can be made to generate student motivation, such as diversifying teaching strategies and resources that are more innovative and creative in line with the wishes and needs of students (Jaafar et al., 2017; Nahar and Safar, 2016; Azli and Azan, 2013). Like the results of a study conducted by Adly and Mardzelah (2016), 100% of respondents admitted that game-based learning could increase their motivation towards learning *Jawi* compared to traditional and formal learning. Therefore, initiatives to restore students' motivation towards *Jawi* learning need to be taken immediately to curb the problem of decline in *Jawi* learning proficiency in the future.

2.2 The Potential of Digital Game Application in Increasing Jawi Learning Motivation

Efforts to foster the motivation of the young generation towards learning *Jawi* should start at the preschool level, but the method of exposure should be appropriate to the natural needs of students (Azli and Azan, 2013). The learning strategies and resources used should be game-based and have a relaxed concept because children's nature is to play (Ashari et al., 2013). A study by Ahmad, Aurani, and Mazlan (2018) shows that preschool students well receive the use of *Jawi* learning resources with an informal concept. In addition, most respondents showed increased motivation and were certified by the teacher that the tool is user-friendly, fun, and supports *Jawi* learning by preschool students (Ahmad et al., 2018). Interactive learning content designed in a digital game-based platform is important to catch attention and stimulate children’s minds' development (Mokhtar, Mohamed, and Sunar, 2019). The active involvement of preschool students can also be fostered using digital game-based learning applications through a combination of game elements adapted to learning, such as challenge elements, rewards, problem-solving, and many more (Behnamnia, Kamsin, and Ismail, 2020). Accordingly, digital game-based learning applications are seen as a *Jawi* learning medium that has the potential to help preschoolers become more motivated.

3. Literature Review

3.1 Mobile Game-Based Learning

Mobile game-based learning is a learning platform that uses games to enhance the learning experience while maintaining a balance between learning content and games (Tan, 2019) applied in the real world (Cózar-gutiérrez and Sáez-lópez, 2016). This strategy requires systematic and consistent planning and organization of each content to achieve each set learning goal (Pho and Dinscore, 2015). According to Perrotta, Featherstone, Aston, and Houghton (2013), the game-based learning approach has several main principles, among which this strategy is implemented voluntarily, a fun learning environment, goal-based learning, the concept of independent learning, and learning through experience. In addition, this game-based learning strategy is an innovation in the education system suitable for all levels of education (Becker, 2016). Three factors of the effectiveness of mobile game learning are the type of games, platform, and technical characteristics (Tan, 2019). These three factors need to be considered and adapted to the student's level to maintain students' active involvement during the class session. In addition, combining learning goals, game design, learning theory, and game elements can produce a game that could improve students' mastery and skill development [21].

3.2 Game Elements for Learning Strategies Based on Digital Games

Improving students' ability, skills, and achievement in doing something is easier through playing experience (Achraf and Youngkyun, 2018). The element of fun found in a game can provide satisfaction without coercion or insistence in learning something without feeling bored (Prensky, 2001). A total of twelve digital game elements proposed by Prensky (2001) are intended as a guide to the developers of digital game application systems in producing game applications that are effective for learning. The elements are fun, play, rules, objective, interactive, adaptive, feedback, win, challenge, problem solving, interactive, and storytelling.

The role of fun elements is to create comfort and increase motivation in a learning process (Prensky, 2001). Next, according to J. Huizenga, W. Admiraal, S. Akkerman (2009), game activities in learning sessions clearly affect engagement, motivation, and mastery. The excitement of playing makes students concentrate and master the lesson (Barzilai and Blau, 2014). According to Prensky (2001), the rule element is to ensure play activities are more organized and purposeful. Accordingly, the objectives of the game and learning need to be clearly stated at the beginning of the game process to inject students with enthusiasm and motivation (Prensky, 2001). The interactive element of a game is intended to make the game seem 'alive' and able to communicate even if the game is used individually without guidance from the teacher or any other party. Therefore, the language used in the game system must be simple, easy, and suitable for the student's level (Prensky, 2001). In addition, elements of representation or storytelling are used to create students' emotions for more fun and passion for completing the game (Prensky, 2001). Furthermore, the element of challenge is to stimulate adrenaline to ensure that the playing process is not boring. Besides that, according to Prensky (2001), each activity or task should start with the easiest level and then move to more difficult levels.

3.3 Digital Mobile Game Based Jawi Learning and the ARCS Motivation Model

A combination of game elements adapted to *Jawi* learning can help increase student learning motivation since it is not direct learning (Prensky, 2003). This method is suitable for preschoolers who are still unable to get involved in formal learning (Ashari et al., 2013). According to Ashari and Baharuddin (2017), teaching subjects related to language and writing through playing methods can support student-centered learning methods. The selection of the ARCS motivational model by John M. Keller for this study is because this model clearly explains the teaching system design by using technology equipment, whether online learning or blended learning, that prioritizes the self-learning method (Keller, 2010).

In addition, the ARCS motivation model also provides a measurement tool that shows the change in student motivation after going through the learning process. Two instruments for measuring changes in student motivation that can be used through the ARCS model are Course Interest Survey (CIS) and Instructional Materials Motivation Survey (IMMS). CIS is used to measure the effectiveness of motivation through teaching methods delivered through face-to-face methods, either directly or online. Meanwhile, IMMS is used to measure changes in student motivation based on the ARCS through student-centered learning using ICT or printed equipment (Keller, 2010).

4. Methodology

The research design for this study is quantitative and one group pre-experimental approach to examine the effectiveness of the *Dunia Jawi* apps. The respondent for this study is preschoolers from one preschool located in one of the cities on the east coast of Peninsular Malaysia. The researcher used purposive sampling techniques and set several criteria for selecting respondents, including being six years old and not having speech difficulties. The study involved 32 respondents from two classes. The development of *Dunia Jawi* Apps was based on the Malaysia Standard Preschool *Jawi* Education syllabus.

4.1 Instrumentation

To assess the effectiveness of the *Dunia Jawi* application, the researcher utilised the Reduced Instruction Material Motivation Survey (RIMMS), which is a revised version of the Instruction Material Motivation Survey (IMMS) initially developed by Keller (2010). The RIMMS questionnaire was chosen for this study as it had been used by other researchers, including Tongco (2007), in previous studies that focused on the use of ICT in preschool education. However, the questionnaire was modified to suit the requirements of this study, with two versions created to evaluate the traditional (*Jawi* education textbook) and game-based learning (*Dunia Jawi* application) methods. The questionnaire items were developed based on the expectancy-value theory and evaluated using a four-point scale and facial reaction symbols to facilitate ease of use for the respondents. Four university lecturers reviewed the questionnaire to ensure its validity by assessing its difficulty level, language, item objectives, and rating scale. An internal consistency test was then conducted, resulting in an overall alpha coefficient value of 0.898.

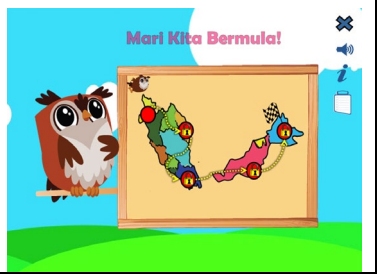
4.2 Development of Dunia Jawi Game-Based Learning Application

The *Dunia Jawi* application offers its content in a game format that is tailored to the respondent's level to prevent boredom during the experiment. To create this content and select the game type, the researcher first needs to assess the student's ability to interact with a touch screen based on their age level, as recommended by Aziz (2013), which suggests that pre-schoolers aged five to six are suitable for using smartphone-based

learning applications as they can operate touch screens by pressing buttons and performing drag and drop movements. The study by Gossen et al., (2015), highlights the importance of designing a specific character to represent the player in the virtual world, using simple language to ensure easy comprehension of instructions, prioritizing the use of pictures over text, and choosing bright colours to keep players engaged. Additionally, the researcher designed large menu buttons for ease of use.

Prensky's twelve digital game elements were prioritized in the creation of content to increase respondent motivation in terms of attention, relevance, confidence, and satisfaction. These game elements not only encourage learning but also boost self-confidence through self-directed learning. Virtual interaction is utilized to help respondents understand all game rules and learning guidelines, with an audio system available for those who cannot read.

Table 1: Prensky digital game elements in *Dunia Jawi* application

Elements	Details	Interfaces
Rules	Guidelines on proper handling methods.	
Objectives/ Goals	Learning outcomes are explained before the game starts.	
Interactive	Every button, character, audio, and animation are designed and developed according to the student's level.	
Adaptive	The game's plot is built on topic difficulty levels, starting from easy topics to difficult topics.	

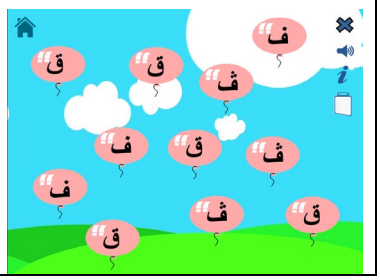
Elements	Details	Interfaces
Win	The final achievement is displayed to enhance the player's satisfaction.	
Challenges	The challenges are designed according to the student's ability.	

Table 1 contains examples of *Dunia Jawi* application interfaces that use Prensky digital game elements, while Table 2 is an example of interfaces that use ARCS components.

Table 2: The motivational component of ARCS in *Dunia Jawi* application

Components	Details	Interfaces
Attention	The use of game concepts, the combination of colors, the selection of type and size of writing, and the use of animation, characters, graphics, and audio must be adapted to the level of preschoolers to attract attention and focus.	
Relevance	Learning goals are informed to ensure students know the game's benefits.	
Confidence	Each game activity includes direct feedback regarding support and total score so that students do not feel that the game is difficult and boring.	
Satisfaction	Rewards are given directly and cumulatively for each level of the game to ensure that students feel appreciated for every effort made.	

4.3 Research Phases

The period of actual research phase was conducted for seven weeks, during which the researcher set each topic in the game application to be completed within one week. Since the *Dunia Jawi* application has five topics, the time required to implement the intervention process is five weeks, and the pre-and post-testing process takes two weeks. Each respondent was allowed to use the game application for as long as needed until they mastered the whole topic.

5. Results and Findings

The researcher used the Wilcoxon Signed Ranks test to identify the differences between respondents' learning motivation before and after using the *Dunia Jawi* application. The following table is the Wilcoxon Signed Rank test results that were obtained from the SPSS.

Table 3 Results of the Wilcoxon Signed Ranks test (motivational questionnaire)

Pair	Min	Max	Mean	SD	Z	Sig(2- tailed)
Books	24	38	31.47	3.417	-4.942	.000
Apps	33	48	43.50	3.370		
α = .05, n = 32						

The study's results in Table 3 indicate that application-based *Jawi* learning has higher motivation compared to book-based *Jawi* learning. The mean value for Apps motivation is higher (43.50) than book motivation (31.47), and there is a significant difference between the two with a p-value of .000, leading to the rejection of the null hypothesis.

5.1 Motivational Questionnaire Analysis of Attention (A) Construct

The first construct analysed is attention (A), where the answers by respondents are summed up according to the book motivation questionnaire and the game application motivation questionnaire. Next, the researcher analysed the following data using the Wilcoxon Signed Ranks test, and the results can be seen in Table 4.

Table 4: Wilcoxon Signed Ranks Test Results (Attention)

Pair	Min	Max	Mean	SD	Z	Sig (2- tailed)
Book	3	8	4.41	1.103	-4.961	.000
Apps	6	12	10.97	1.332		
α = .05, n = 32						

Table 4 shows that the game application attention construct has a higher minimum score value of 6, compared to the book attention construct (3). Similarly, the maximum score value for the game application attention construct is higher, with a total of 12 compared to the book attention construct (8). The mean value for the game application attention construct is also higher than the mean value for the book attention construct at 10.97. These findings suggest a significant difference in *Jawi* learning motivation for the attention construct before and after using the *Dunia Jawi* game application, with a p-value of .000, leading to the rejection of the null hypothesis.

5.2 Motivational Questionnaire Analysis of Relevance (R) Construct

The second construct analysed using the Wilcoxon Signed Ranks test is relevant (R). The following table is the Wilcoxon Signed Ranks test results that have been conducted on both questionnaires.

Table 5: Results of the Wilcoxon Signed Ranks test (relevant construct)

Pair	Min	Max	Mean	SD	Z	Sig (2- tailed)
Book	8	12	10.63	1.040	-1.754	.079
Apps	9	12	10.97	.695		
α = .05, n = 32						

Based on Table 5 above, it can be observed that the minimum score value for both questionnaires only differ by one mark, and there is no difference between the two maximum score values. Although the mean value for the *Dunia Jawi* game application questionnaire is higher than the mean value for the book questionnaire, the significant value obtained is p =.079, where the p-value exceeds the significance level, which is p <.05. Thus, it can be concluded that the null hypothesis fails to be rejected because there is no significant difference between the motivation of learning *Jawi* using books and the motivation of learning *Jawi* using *Dunia Jawi* application.

5.3 Motivational Questionnaire Analysis of Confidence (C) Construct

The following table is the result obtained through the Wilcoxon Signed Ranks test for the confidence construct.

Table 6: Results of the Wilcoxon Signed Ranks test (confidence construct)

Pair	Min	Max	Mean	SD	Z	Sig (2- tailed)
Book	5	12	8.41	2.092	-4.261	.000
Apps	7	12	10.31	1.378		
α = .05, n = 32						

In the table above, the difference between the minimum confidence construct value by the book is lower than the minimum confidence construct value by the *Dunia Jawi* application, which is the value is 2. Although there is no difference between the maximum score value, the mean value of game application confidence is higher than that of book confidence, with a value of 10.31. In addition, the test results show a significant value of p = .000, which shows a significant difference in the students' *Jawi* learning motivation in terms of confidence before and after using the *Dunia Jawi* game application. Therefore, the null hypothesis is successfully rejected.

5.4 Motivational Questionnaire Analysis of Satisfaction (S) Construct

The Wilcoxon Signed Ranks test analysis results for the satisfaction construct are shown in Table 7 below.

Table 7: Results of the Wilcoxon Signed Ranks test (satisfaction construct)

Pair	Min	Max	Mean	SD	Z	Sig (2- tailed)
Book	4	12	8.03	1.909	-4.782	.000
Apps	8	12	11.25	1.016		
α = .05, n = 32						

Based on the table above, the minimum score value obtained for book satisfaction is lower than game application satisfaction, with a different value of 4. However, there is no difference between the maximum score value for both satisfaction constructs. Nevertheless, the respondent's satisfaction with using game applications for *Jawi* learning can be seen from the mean value obtained for the game application satisfaction construct, with a value of 11.25, compared to the book satisfaction construct, with a value of 8.03. A significant value shows p = .000, where there is a significant difference between the construction of *Jawi* learning satisfaction of preschool students using books and game applications. Therefore, the researcher successfully rejects the null hypothesis.

6. Conclusions

The mean value difference shows that using digital game technology based on the ARCS motivation model effectively increases pre-schoolers' *Jawi* learning motivation. Study from Shih-Yeh Chen, Chao-Yueh Hung, Yao-Chung Chang, Yu-Shan Lin (2018) supported this finding, indicating that interactive technology-based learning increases student engagement, concentration, and duration of self-learning. In addition, the findings in terms of constructs show that there is a significant difference between the use of books and *Dunia Jawi* game applications for attention, confidence, and satisfaction. However, for relevant constructs, the findings show no significant differences. This finding shows that the respondents gave a fair view of the benefits of using books and game applications to learn *Jawi*. According to a study by Sharmin et al., (2020), this finding resulted because, both types of teaching content and structure, whether using books or technology-based learning aids, have the same benefits and objectives. However, the mean value comparison suggests that the *Dunia Jawi* game application is more relevant than the book.

Next, the findings for the attention construct prove that different learning approaches that contain technology elements are indeed proven to be able to attract the attention of today's students. This finding is supported by the results of previous studies conducted on preschool students using mobile game applications, where the use of touch screen technology successfully attracted their interest and active involvement in the learning process (Fatimah, Ainol, and Shafitra, 2012). Furthermore, another study found that mobile technology-based learning approaches increased perception and learning skills, likely due to the feeling of fun and excitement during the learning process (El-Sofany and El-Haggar, 2020).

Lessons involving language or pronunciation that are newly introduced to students are easier to learn by using a game approach where students are in a relaxed situation that allows them to explore and try to speak confidently without feeling shy. This finding is supported by the results of previous studies by Griva et al., (2010), the group of respondents who were taught foreign language subjects using a game approach managed to get high scores and were confident in speaking in a foreign language compared to the group of respondents who were taught traditionally. The respondents in this study were able to achieve satisfaction through a digital technology-based learning approach that offers interactive and fun learning, as demonstrated in the study by Chin et al., (2015). The study found that respondents felt happy and satisfied when completing assignments using an interactive learning system and were excited to continue learning through this approach in the future. Furthermore, the feedback system, rewards, and winning components of interactive learning, as shown in the results of study from Chang, Hwang, Fang, and Lu (2017), help students maintain their self-satisfaction until they successfully complete each learning task.

7. Limitations and Recommendations

Although there is a provision of tablets for use in schools, limitations exist when the amount required is insufficient for individual students to use. Therefore, students can only use this application at home as a reinforcement exercise. The application developed for this study only focuses on the use of preschool students. Therefore, it is hoped that in the future, there will be researchers and application developers who will continue to develop this application for the use of high-level students.

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Development of an Enjoyable Educational Game on Fundamental Programming: Designing for Inclusion and Learning Analytics

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Abstract: A well-discussed problem is how to attract a new public to computer programming, and especially how to reach girls and women. At the same time research reports on that children spend considerable amounts of time playing different types of games, where educational games today are part of formal, informal and non-formal learning. However, many educational games still have a design that appeals more to boys than to girls. Another problem addressed in this paper is how to measure the learning outcomes of an education game. It is a challenge per se to design for joyful gaming, but to assess the learning outcomes is important if the game should be accepted by teachers and a part of teaching and learning activities. The aim of this study was to describe and discuss the design and development of an educational game where girls would like to play together and at the same time learn fundamental programming. The research question that guided this study was: " *How could a motivating and inclusive educational game on fundamental programming be designed and developed, with minimal prerequisites for students and teachers?*". The overall strategy for the design and development of the was the Design Science Research (DSR) approach. This work was carried out according to the recognised DSR process with the five phases of: 1) Explicating the problem, 2) Defining the requirements, 3) Designing and developing the artefact, 4) Demonstrating the artefact, and 5) Evaluating the artefact. Phase one was based on a minor literature study, while Phase 2 was a combination of a larger and more systematic literature study combined with game testing. Phase 3 was conducted with brain storming sessions for design followed by implementation in the Unity game development tool. Finally, the game has been demonstrated for, and tested by, a group of academic game developers. Results from the formative evaluation look promising, but the important next step in this project is a more formal evaluation using game-based learning analytics with a larger and more diverse test audience.

Keywords: Game-based learning, Game design, Inclusive design, Game-based learning analytics, Programming education

1. Introduction

Previous research shows that students' interests in Computer Science (CS) and programming courses have been increasing (Zweben & Bizot, 2016; Sax, Lehman & Zavala, 2017). However, the larger number of potential students have put strains on CS faculty and personal to find strategies for course execution and logistics that do not negatively impact underrepresented groups in CS courses, such as women and students of colour (Camp et al., 2015; Kaczmarczyk et al., 2015; Sax, Lehman & Zavala, 2017). Today, games are part of everyday life for both children and adults. According to a report, 6 out of 10 Swedish internet users play games on either mobile devices, computers, or gaming consoles (Internetstiftelsen [The Swedish Internet Foundation], 2022). Games are also widely used for learning, both formal (Pan, Ke & Xu, 2022; Humble & Mozelius, 2022), informal (Koutromanos & Avraamidou, 2014; Humble, Mozelius & Sällvin, 2021), and non-formal (Pienimäki, Kinnula & Iivari, 2021).

Although games have been used for educational purposes for a long time (Hellerstedt & Mozelius, 2019; Mozelius & Humble, 2023), research show that girls and women does not engage in games with the same passion as boys and men (Cassell & Jenkins, 2000; Carr, 2005; Lima & Gouveia, 2020; Mozelius et al., 2022). Previous research has also noted that although games are popular for educational purposes, their effectiveness for learning have been insufficiently studied (Yu, Gao & Wang, 2021). That the games used in educational context have positive impact on students' learning outcomes is of course important if games are to be accepted as teaching and learning tools by teachers and other educational stakeholders. The aim of this study was to describe and discuss the design and development of an educational game where girls would like to play together and at the same time learn fundamental programming. The research question that guided this study was:

> *How could a motivating and inclusive educational game on fundamental programming be designed and developed, with minimal prerequisites for students and teachers?*

2. Method

This study used a Design Science approach involves the second and the third phases of the five-phase process that has been outlined by Johannesson and Perjons (2014). The two phases that were conducted and described in this paper were 2) Defining the requirements and 3) Designing and developing the artefact. All the ingoing phases in the Design Science process are depicted in Figure 1 below. The first phase of explicating the problem, and a beginning of phase 2 has been conducted earlier and was published in Mozelius et al. (2022).

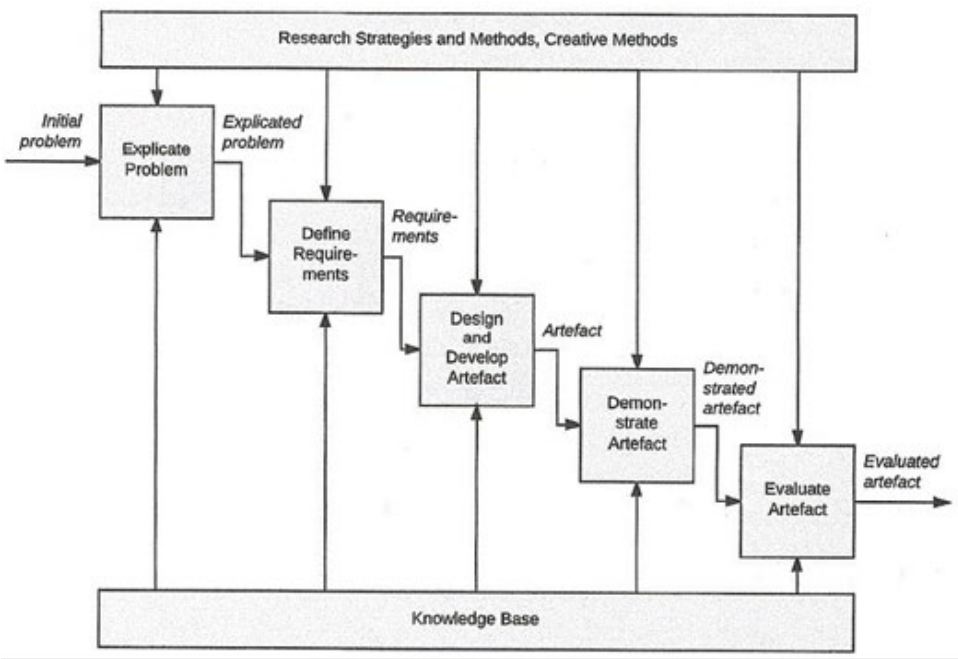

Figure 1: The five phased Design science framework (Johannesson & Perjons, 2014, p. 82)

Phase 2 was carried out in a combination of a larger and more systematic literature study that has been combined with testing of other educational games on fundamental programming (Sällvin, Mozelius & Humble, 2023). Phase 3 was conducted by project members in brain storming sessions on appropriate and creative game design. Later the design ideas were implemented with use of the Unity game development tool. A start of phase 4 and phase 5 was initiated when the game was demonstrated for, and tested by, a group of academic game developers. What remains, in a longer journal article, is to describe and analyse all the five phases in Figure 1. This should be done when phase 4 and phase 5 have been completed with demonstration and more formal testing by the presumptive target audience.

3. Requirements

The second phase of the design science research process involved defining the requirements. This was accomplished through a systematic literature review, which aimed to identify important game design concepts for engaging both girls and boys in serious gaming (Mozelius et al., 2022). Those results are in line with other literature reviews such as (Sharma et al, 2021). Additionally, three existing educational programming games were tested by girls between the ages of 10 and 15 (Sällvin, Mozelius & Humble, 2023). The findings from the literature review and the testing phase can be summarized as the game design recommendations presented below. The literature review was conducted during the spring of 2022, and the game was tested in a Maker movement girl group during the autumn of 2022.

3.1 Creativity, Customisation and Character diversity

Examples of this include providing players with the ability to create items for use within the game and incorporating functionality that allows customization of game environment components, such as modifying game characters. Games featuring a mix of male and female characters or non-gender-specific characters are preferable.

3.2 Exploration Without Violence and Collaborative Interaction

The literature review showed that while boys are often drawn to games involving combat and violence, girls tend to prefer indirect competition without violence. An educational game targeting both girls and boys should strive to incorporate explorative gameplay with a compelling narrative or diverse activities, engaging characters, and opportunities for collaboration and social interaction.

3.3 Flow and Mastery

The sense of flow and of being in control is important not to lack motivation. Challenges and tasks in the game should therefore be aligned with the player's competence level to achieve an optimal level of engagement and motivation.

3.4 Reward and Feedback

Rewards, such as virtual currency, unlocking new levels or abilities to customize the avatar, for accomplishing specific goals keep players engaged and motivated. Feedback and guidance in the form of messages and hints are important in educational contexts, as it provides valuable information to learners and facilitate the enhancement of their programming skills. The possibility to fail and try again is also highly valued.

In addition to these motivating and inclusive design recommendations, there are also two other requirements that should be considered. Firstly, the game should include mechanisms to measure learning outcomes. Secondly, it is essential for the game to be easily adaptable for use by teachers and students, with minimal prerequisites or technical barriers.

All the above recommendations served as the requirements and the foundation for the next step in the design process, where the game design was developed through brainstorming sessions with the project members.

4. Game development

The theoretical thoughts explained above resulted in the creation of an initial game concept which was later expanded iteratively during the autumn and winter in 2022 and 2023. The declared goal of the game was to help students learn computational thinking skills and fundamental coding skills in Python. Another decision was to focus on the age group of 10–16-year-old students without earlier programming experience. Furthermore, it was a requirement that the game would be attractive enough to make people want to play it and not just see it as a learning tool and, most importantly, that it should use a girl-inclusive design. These requirements and intentions shaped the idea of focusing on a few essential game elements that are proven to work well from a game design perspective and that are addressing the outlined requirements.

The core idea of the game is that players collect cute fantasy creatures called ‘critters’ which can be trained by giving them instruction scripts. The training is purposefully not called programming in order to give the game less of a technical feeling. The main gameplay consists of collecting interesting critters, training them for racing and entering them into a race against other players. Races are held on different obstacle courses. The critters compete either against bots, or against other players. Four proven elements are implemented at the heart of the game:

4.1 Collecting

The activity of collecting things has a large appeal as a game element, especially when the player can collect creatures. The most prominent example of this is the Pokémon GO game. Since new creatures are awarded for winning races or for other achievements the interest in collecting critters has a strong impact on the motivation of the players to get better at coding, leading to that collecting new critters becomes easier.

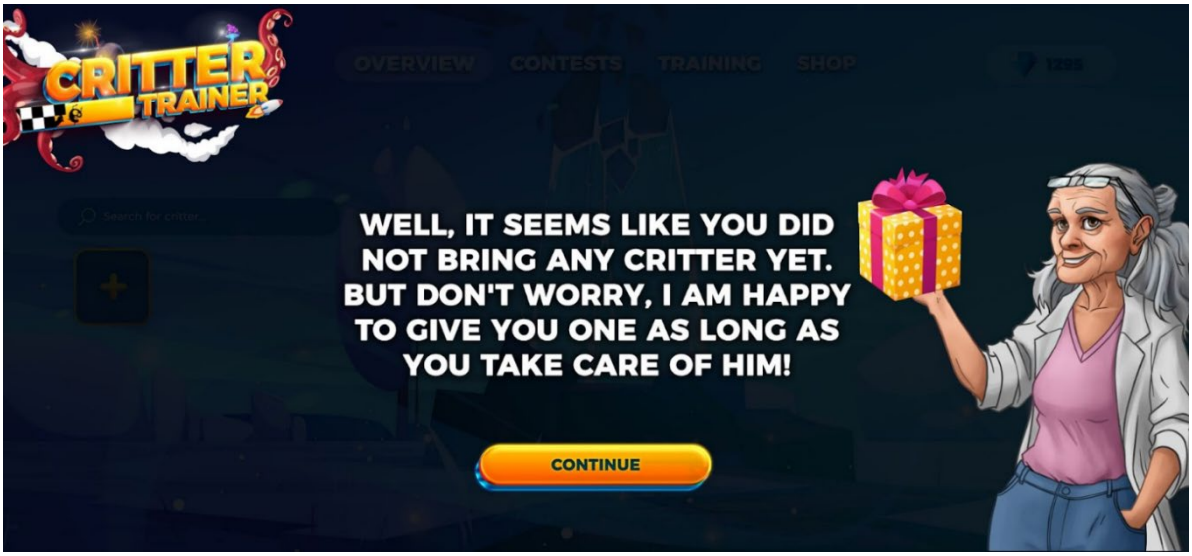

Figure 2: A critter to take care of and to train

Competition

The competition element is a well-established way to challenge a player to become better. The game uses a mixture of players and bots as competitors so that the player always has the opportunity to win against someone, even if it is too hard to win first place. Competition should also give players an opportunity to learn from others.

Rewards

Rewards are very important for player motivation. The game rewards victories in races so that players get something out of having created well-working training scripts for their critters. However, the game also rewards personal achievements, even if the player doesn't end up winning the race. Thus, rewards play an important role in keeping the motivation high for any learning and gaining of experience. The biggest rewards are new collectable critters, smaller rewards are special items for the critters and trophies.

Difficulty matching

The game uses a smart algorithm to assign competence levels to players in order to match them with other players or bots that are performing at comparable levels. This avoids having a beginner crushed by a very advanced player.

Python syntax was chosen for the coding elements since Python is one of the most popular programming languages which is also widely recommended for school environments in Europe. It is also a programming language with high readability and high writability that is easy to learn. In the actual game the players first learn how to give critters commands in order to guide them through an obstacle course. Commands correspond to functions in Python but the players will be using predefined functions from the beginning (such as run, dodgeLeft, dodgeRight, and jump) before learning how to create their own functions. The game starts with tutorials which challenge the player to solve a situation, so they are essentially little puzzles that help the player acquire the skills needed. The tutorials gradually introduce the player to the competitive racing game in which more critters can be unlocked and rewards can be won.

Of course, the tutorials can be skipped and the players can immediately start training their critters and enter them into races. In a race the player only has limited control over the critters as they are mainly in the role of a spectator. Winning or losing a race has a lot to do with which critter is selected for the race track and which commands are given to the critter in a 'training script'. When training a critter, a player writes down a sequence of commands which the critter will execute in the race. This could start in a very simple way (' run ', ' run", ' run ', 'jump') as in Figure 2 below, and then move to more advanced coding structures with while loops and conditionals.

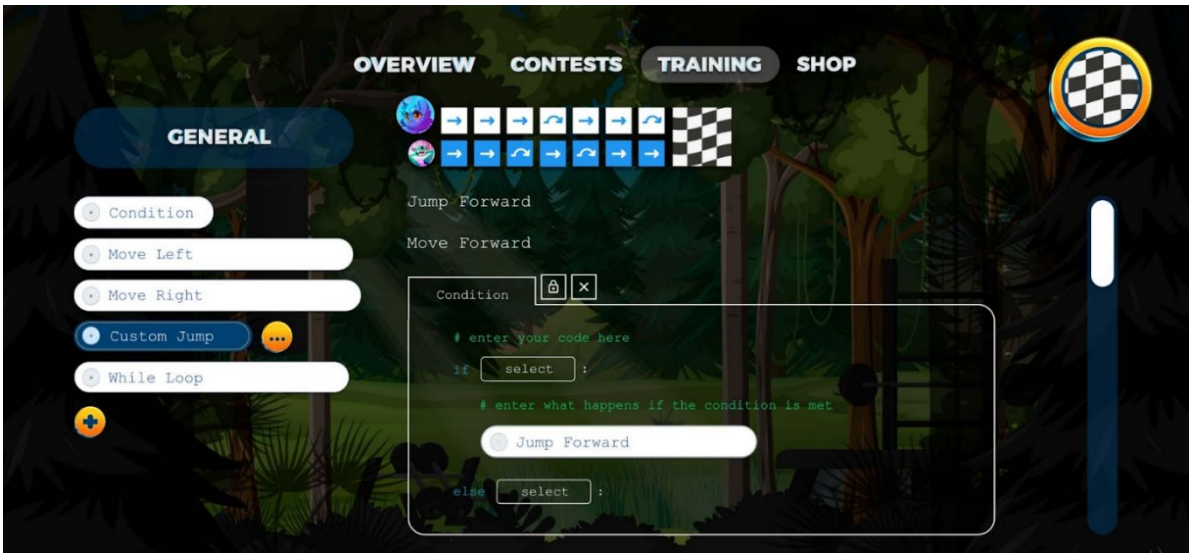

Figure 3: Creating code scripts for training and contest

The game never pushes the player to advance in the coding skills, however the competitive aspect and the rewards for winning races are a huge motivation to improve the performance of the critters, thus leading to players trying out more advanced code. As a framework for the development, Unity was chosen since it has become a standard for game app development. The advantage of using a framework like Unity is that a lot of the movement of objects on the screen (in essence the interaction between critters and race track) can be implemented fairly easily and without days of programming work. A first alpha version has been tested by a group of academics with experience of game design and game development. The testing was carried out, at two universities during April and May 2023. Several bugs were discovered and there is a need for a revision before the game meets a wider audience. At the same time the graphics and the general game idea got positive feedback.

5. Game-Based Learning Analytics

The use of games to enhance the learning of programming in schools is something that has already started to be used, and where different examples can be found. There is a wide variety of games and approaches ranging from promoting the teaching of computational thinking concepts to learning a specific programming language (both board games and videogames), or even relating programming to physical robots (Malliarakis et al, 2014; Jordaan, 2018). However, as with other serious games, it is not so often that the results have been scientifically validated and it is even very rare that such evaluation has been done in a systematic way with a large number of students and supported by evidence of the results obtained (i.e., based on usage data and not only on self-assessments or student perception and acceptance) (Sharma et al, 2021).

Game learning analytics (GLA) comprise the collection, analysis, and visualization of player/student interactions with serious games. The information gathered from these analytics can benefit all the stakeholders in the game development helping us to improve serious games design and implementation and improving their educational use by better understanding player actions and strategies, as well as improve player assessment (Alonso-Fernandez et al, 2022). However, to obtain significant GLA results, it is necessary to have a learning analytics model that can relate the interaction data obtained to the educational design of the game. This model allows that a more comprehensive analysis can be made to identify potential game design problems and gain insight how actual student learning develops with the game (Perez-Colado et al, 2018). We also consider that it is necessary to systematize the GLA processes as this will allow to scale up GLA use and to have data from a significant number of students. One way to achieve this systematization is through standards and open software. In our case, we use the new standard eXperience API (xAPI) as it has an application profile for serious games (xAPI-SG) which simplifies both the collection and analysis of data. GLA will be compliant with European regulations for data privacy (e.g., EU GDPR) informing students that data is being collected and that will be used only in an aggregated way to improve the game and the educational experience. All the data captured will be

pseudo-anonymized at the origin so that it cannot be traced back to any specific student (students will play with a code without providing their personal details).

In this project, we are currently carrying out a formative evaluation of the game with the aim of improving it for testing with end users (i.e. learners). In addition to the usual testing with game experts (e.g. beta testing), we are incorporating GLA. For a game to be effective, testing with experts is not enough and early formative evaluation based on data about learners' behaviour and progress in the game is necessary. To this end, we want to start early testing that will allow us to improve both the game and the GLA process applied to this programming learning game. Specifically, we want to:

- Compare and improve the instructional design: GLA can be used to check whether the game is well designed from both a gameplay and pedagogical point of view. The aim is to identify areas where learners have difficulties (e.g. non-progressive gameplay situations) and to be able to correct them by improving the user experience.
- Evaluate the effectiveness of the game as a learning tool: GLA can be used to evaluate the effectiveness of the game as a learning tool by measuring student progress and learning outcomes (e.g. related programming concepts). This information can be used to make improvements to the game or to make informed decisions about whether to use the game in future learning experiences.

Thus, the purpose of the GLA is to improve the overall quality of the game, but it requires a thoughtful and responsible approach to implementation to be effective. By providing information about learner behaviour and progress, and at the same time having a model that attempts to relate this data to the instructional design of the game, it is possible to test whether the initial assumptions are being met. All this analysis should be driven by and related to the educational design of the game. Only with this approach, GLA can help to ensure that serious games are effective and engaging learning tools that meet learners' needs. A project meeting was held in March 2023 to discuss how the game-based learning analytics should be implemented in the game.

6. Discussion

The first results from the formative evaluation look promising, but what is of greater importance is the next step, to carry out a more formal evaluation for the intended target group. An evaluation where the game will be tested both in girl groups, and in groups that are as heterogeneous as possible, but within the aimed age group. Moreover, the described GLA will be implemented to provide data that could improve the user-friendliness and the instructional design in the Critter trainer game. Test results that later will be used as input for the next five Design science phase iteration, before the game should be made public and downloadable from the project's web portal.

Using video games in classrooms can provide a different and more active way to build and explore their learning and help break down stereotypes. It also allows children to explore and enhance their digital, creative, and problem-solving skills, which can change perceptions and help girls become more interested in STEM disciplines in general and in programming in particular (Sharma et al, 2021). While GLA analytics can be powerful, it is not a magic solution that will automatically lead to improved learning outcomes. The data collected through GLA must be carefully analysed and interpreted to draw meaningful conclusions about learner progress and areas of difficulty. In addition, the data must be correlated with the instructional game design to provide relevant insights into the learning experience.

7. Conclusion

Although the use of games to increase students' motivation is not new, it seems clear that there is still a need for more systematic projects to better understand the relationship between girls' gaming behaviour, game design and their perception of programming and computer science careers (Sharma et al, 2021). However, game-based learning analytics must be implemented with careful consideration for learner privacy and data security (e.g., EU GDPR compliance). Learners must be informed that interaction data is being collected to improve both the game and the educational experience (as previously mentioned, all the data captured will be pseudo-anonymized at the origin so that it ca not be traced back to any specific student).

8. Future Work

The work presented here in this paper is a part of a two-year European project with the aim of developing, testing and disseminating the described educational game. As the next important step in the project, the game

should be demonstrated and evaluated in different test groups. Some test groups will consist of girls only, while other test groups should be as heterogeneous as possible, but with participants from the intended age group.

Acknowledgement

This study was made possible by funding from the Erasmus+ project Gaming4Coding. This is a two-year project, with the overall purpose of designing and developing a game where secondary school students should learn text-based programming. Moreover, the game should be a joyful experience for players, and it must be a game where girls should feel welcome to play and learn together with boys. The project builds on the idea that the highly motivating features of game-based learning could be used to promote the learning of programming in a younger audience, and especially among girls.

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A Conflict Management Game in Project-Based Learning

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Abstract: In project-based learning environments, students often face team frustration and conflicts, necessitating the development of conflict management skills. This study examines how integrating a game-based learning approach impacts students' perspectives on managing conflicts in game development project courses. Drawing on theoretical frameworks related to project-based learning, conflict management, and serious games in conflict resolution education, a case design is employed in higher education that incorporates the game "Cards of Conflict". Document analysis of student reflection notes is utilised to assess the outcomes. The results demonstrate heightened engagement among participants during the game session, leading to awareness and understanding of conflict managing principles. This encompasses the what, the why´s, and the how's of conflict management, as well as the diverse perspectives of peer students.

Keywords: Game-based learning, Serious games, Project-based learning, Conflict management, Game development, Higher education, Team-based student work

1. Introduction

The issue of Information Technology students experiencing frustration during their university studies is a widely recognised and well-known problem (Hansen and Eddy, 2007; Chan-Lin, 2008; Huff and Clements, 2017). This frustration can arise from various sources, especially when students collaborate on group projects (Kolås and Munkvold, 2017). Research has shown that student frustration should be considered an academic emotion in learning environments. The term "Academic emotions" is used to address emotions directly linked to academic learning, classroom instruction, and achievement (e.g. enjoyment of learning, pride of success, or test-related anxiety" (Kolås and Munkvold, 2017; Pekrun et al., 2002). One possible strategy to prevent frustration from turning into negative emotions is scaffolding (Vygotsky, 1978). Scaffolding can be a helpful approach in project-based learning to prevent students from feeling overwhelmed and facilitate their personal growth. Scaffolding is a metaphor used by Wood, Bruner and Ross (1976) where they seek to operationalize the concept of the zone of proximal development (ZPD). ZPD indicates the distance between what a student can do with and without help (Vygotsky 1978) and how one by supporting the learner – step by step (scaffolding), will guide and help them become self-regulated learners. Regarding conflicts among students, providing better strategies for handling team conflicts is one possible scaffolding approach. The present study explores a game-based scaffolding approach, Cards of Conflict (CoC), to answer the research question (RQ): *In what ways do CoC influence students' perspectives on managing conflict in project-based courses?* CoC is a novel discussion-based serious game designed and developed at [redact] that introduces conflict scenarios that may arise in student projects.

2. Theoretical Foundation

The theoretical foundations of this study focus on project-based learning, conflict management, and serious games in higher education.

2.1 Project-Based Learning

Project-based learning is an inquiry-driven teaching approach involving students in creating knowledge by having them complete significant projects and develop practical, real-world products (Guo et al., 2020). It is an approach in education to ensure that students learn not only hard skills, like cognitive knowledge and professional skills, but also soft skills, problem-solving and teamwork, which are needed in their future workplaces (Guo et al., 2020). According to Sindre et al. (2018), project-based learning in higher IT education can vary based on nine different characteristics, for example, to cover part of or a whole course; range from one to many courses; having a "theory first", a "theory-project" or a "project first" approach, involving non or other stakeholders, be organised individually or in teams, using a variety of assessment methods, being the same project or unique or self-selected by students and ranging from a well-specified to flexible process and/or product. The creative media industry emphasises the importance of future candidates' interpersonal/social and communication skills. Teamwork is widely used as a work approach and where the mentioned skills are fundamental (Curda, 2021;

Manevska et al., 2018; Tyson, 2020). Conflict often emerges within collaborative project-based teams, so conflict management is a concrete skill when learning interpersonal/social skills.

2.2 Conflict Management

Donohue and Kolt (1992) define conflict as "a situation in which interdependent people express (manifest or latent) differences in satisfying their individual needs and interests, and they experience interference from each other in accomplishing these goals" (p.4). They also claim that conflicts are a fundamental part of human life and that we can use it to build better lives if we know how to manage them. Even though many assume conflicts are harmful and should be avoided, Algert et al. (2021) claim that conflict is neutral and that how one engages in the conflict can be perceived as constructive or destructive. They further conclude that "the key to managing conflict is to expect, understand and embrace conflict in a manner that allows it to benefit individuals and the organisation" (Levin and Rolfsen, 2015). Levin and Rolfsen describe how conflicts are crucial to developing an effective team and refer to Lencioni's model of dysfunctionalities in teams, where "fear of conflicts" is emphasised.

Teaching students effective conflict resolution skills can draw upon various models and approaches. For example, Fisher, Ury, and Patton (2011) present a highly regarded step-by-step approach to resolving conflicts and achieving mutually beneficial agreements. Based on the principles of the Harvard Negotiation Project, their method emphasizes separating individuals from issues, focusing on underlying interests rather than rigid positions, and generating creative options for shared benefits. Another influential framework is Levin and Rolfsen, (2015) five-stage approach, which consists of *Denial/Avoidance, Compulsion, Negotiation, More Information Leading to Problem-Solving*, and *Reframing of Reality* (Levin and Rolfsen, 2015).

While numerous conflict management models exist (Lynch, 2001; Slaikeu & Hasson, 1998; William et al., 1988), many share similarities. The Thomas-Kilmann conflict model was chosen as the foundation for the CoC framework based on a review of previous research and expert recommendations from the field of educational psychology. This decision aimed to provide students with a well-rounded and effective approach to handling conflicts and fostering collaborative problem-solving.

2.3 Serious Games in Conflict Resolution Training

Conflict resolution is essential for navigating social interactions, as conflicts are inherent in human relationships. Developing effective conflict management and resolution skills enables individuals to address disagreements constructively and positively (Cheong et al., 2015). However, teaching conflict resolution has proven difficult due to creating authentic learning environments and predicting how people behave in real-world conflict situations (Campos et al., 2012). Simulation and game-based learning scenarios have been proposed as potential solutions for teaching conflict resolution skills to both adolescents and adults as these often are designed to trigger emotions and engagement. Serious games, designed with a primary purpose beyond entertainment, often focus on teaching new skills through engaging and challenging experiences (Susi et al., 2007; Landers et al., 2017; Roy and Zaman, 2017).

Several reasons support the use of serious games in education and learning. Games are interactive, allowing participants to experience the consequences of their choices and receive direct, formative feedback essential for learning (Lieberman, 2006). Games can also foster social interactions, providing opportunities for skill development and collaboration (Trepte et al., 2012). Many games naturally incorporate conflict resolution as players collaborate to resolve disagreements and create a positive gaming experience (Cheong et al., 2015). In some game contexts, players must negotiate and find mutual solutions to problems, with cooperation often leading to better chances of success. These situations offer safe environments for learning conflict resolution skills without resorting to violence or negative behaviours (Bartels et al., 2013).

Various design approaches exist for teaching conflict resolution through games. One example involves using a chatbot as a conflict mediator in role-play scenarios within a virtual environment (Emmerich et al., 2012). This approach emphasises collaborative learning but faces challenges due to the chatbot's limited language comprehension. Another approach involves human facilitators guiding conflict resolution role-plays (Powers and Kirkpatrick, 2013). While more resource-intensive, human facilitators enable valuable oral briefing and debriefing sessions, crucial for knowledge transfer in serious games (Crookall, 2011; Taylor et al., 2012). Requiring participants to write debriefing reports also promotes reflection on their actions in simulated conflict situations, integrating their game experiences with real-life lessons (Powers and Kirkpatrick, 2013).

3. Methodology

This research aims to investigate the influence of CoC on students' understanding of conflicts and associated strategies. The study was designed as a case study (Merriam, 1998) concerning a CoC. The case was discovery-led, not based on existing theories (Martyn, 2010) and explored using a game session in a higher education course. The study used student reflection assignments as primary data. A secondary data source, observation records scribed by Author 2 during the CoC play session, were used. The notes, however, were used as a reference point during the thematic analysis and had a superficial part in the study outcome.

During the study, students played a game called CoC, which aimed to orient and equip them to handle conflicts in student projects. The research was conducted using the following materials and methods.

3.1 Participants

The study involved a diverse group of 19 first-year undergraduate students who were enrolled in an international game development program at a Norwegian university. These participants, consisting of four females and fifteen males, had an age range between 19 and 31 and represented a mix of nationalities and backgrounds, reflecting the global nature of the game industry. As aspiring professionals in the field, they brought with them a range of interests, skills, and experiences related to game design, development, and play.

3.2 Game Artefact

CoC is a serious game designed to equip students to handle conflicts that may arise during a project. The game design is research-based, incorporating the concept of conflict resolution strategies (Xia et al., 2020) and the Thomas-Kilmann conflict model's five modes of conflict management: *Accommodating, Avoiding, Compromising, Competing,* and *Collaboration* (2021). CoC presents 12 realistic conflict scenarios, each with possible solutions focusing on Thomas-Kilmann's five modes and strategies for managing conflicts. The game requires students to work in teams to discuss and agree on the best conflict resolution strategies.

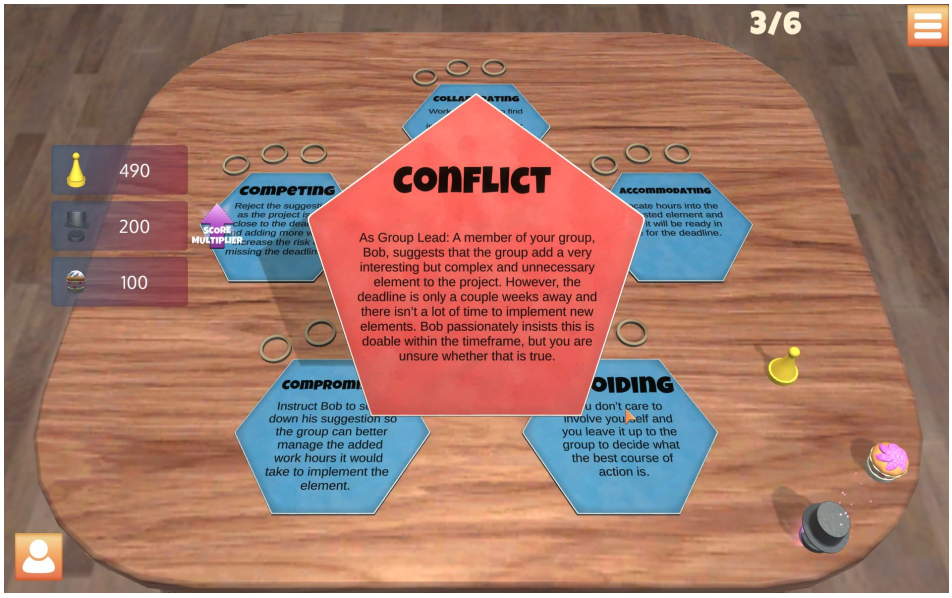

Figure 1: The CoC interface showing one the conflict scenarios and five conflict managing strategies

In the CoC game, the instructor acts as the game master and leads the session for participating teams. Each group is presented with a typical scenario that students could enter during the studies and five possible ways to resolve the conflict. The students have a limited time to discuss and reach a decision. The teacher then asks each group for their choice and provides the correct solution, which may have multiple correct answers. Points are awarded accordingly, and the scoreboard is displayed before moving on to the next scene.

3.3 The Game Session

The students' first meeting with the game was playing it together in a game session led by the teacher. The game session began with an introduction to CoC and reasons for its importance, followed by an explanation of the five conflict management styles using examples. Students were randomly divided into four groups for the game session. The instructor read the conflict scenarios and the possible solutions out loud. The students were further

given around 1 minute to discuss and agree upon one of the solutions, which upon the right solution was revealed and in-game points were added to the different teams. Post the joint CoC session, the students were given an individual assignment to reflect upon the experience of playing this game.

3.4 Student Reflection Assignments

Students participating in the study completed an individual written assignment reflecting on their experiences playing CoC on two occasions (in-classroom and individually), where their debriefing reports promotes reflection on their game experiences with real-life lessons (Powers and Kirkpatrick, 2013). In the student assignment, they were instructed to provide insights into how the encounters with CoC influenced their perception of conflict and their experiences working in project-based student teams. The assignment covered various topics, such as their prior experiences with conflicts and conflict management in project-based courses, their impressions of playing the game within a classroom setting compared to playing it individually, and their overall experience of participating in the exercise. To facilitate deeper reflection, students were granted access to the game while working on their reflection notes, allowing them to replay the game individually to examine further and analyse their thoughts and experiences.

The student's reflection assignment notes were then evaluated using a document analysis as described by Bowen (2009). Examining the students' experiences through this comprehensive reflection assignment aimed to provide valuable insights into the game's effectiveness in improving students' understanding of conflict management and enhancing their ability to work collaboratively within project-based teams throughout the semester.

3.5 Data Analysis

Student reflections from game session notes were subsequently analysed using a thematic analysis approach (Braun and Clarke, 2006) to the coding and categorisation process. The analysis primarily focused on identifying similarities in the participants' game experiences. Author 2 observational data was then employed for comparative purposes, juxtaposing observational data with students' reflection notes. The data underwent three coding and categorisation phases. The initial phase of reading their responses provided a glimpse into their perspectives and potential categorisation. In the second phase of reading, coding and analysis, the categories were further clarified, enabling the enumeration of occurrences within each category. The coding, clustering, analysis, and author discussions unfolded iteratively, ultimately merging the initial categories into more broad, overarching categories. In the third phase, the iterative analysis process encompassed inductive and deductive coding, resulting in two themes emerging from the data set.

4. Result

Two main themes regarding CoC initially impact students' perspectives on conflicts concerning project-based game development. Findings indicate that CoC influences student social interaction during gameplay, raising comprehension and self-awareness of conflict management (Figure 2).

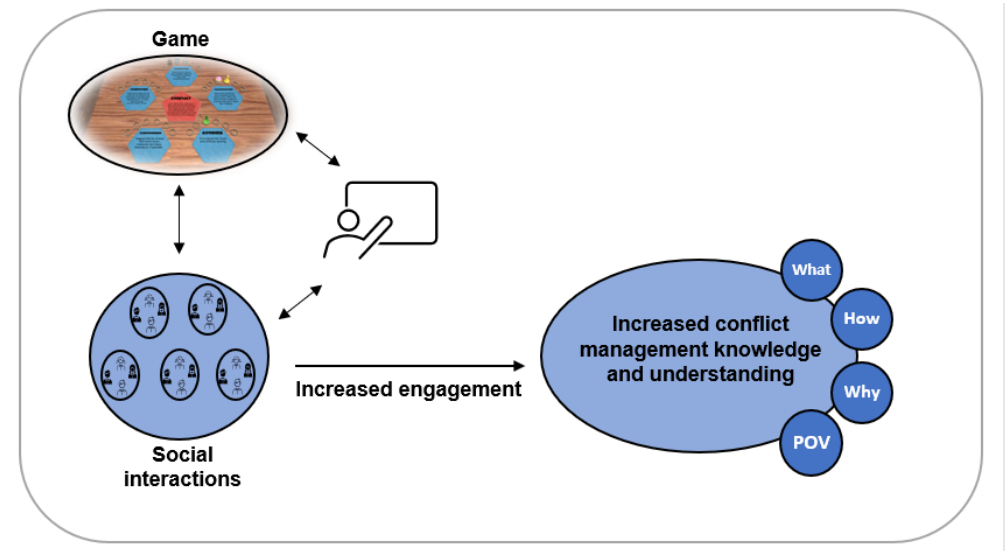

Figure 2: Potential knowledge acquisition trajectory for CoC

4.1 Rising Awareness and Comprehension

There is evidence to suggest that the CoC had an impact on the students' overall understanding of conflicts. The thematic analysis of their reflections reveals an awareness of the reasons behind conflicts arising in student-run projects. Additionally, it highlights the importance of recognizing multiple perspectives and finding ways to reconcile with team members' standpoints in order to effectively address conflicts.

> *"Personally, before playing the game, I would have only used some of the methods listed and would never have considered something like competing or avoiding as an adequate solution, but the game and discussion helped open my mind to the possibility of using those conflict styles." Excerpt 1*

> *"More prepared on how to deal with other peoples' issues […] In the play session, I learned how there are different approaches to a conflict and more than one side to a conflict which you can take […] the game and discussion helped open my mind to the possibility of using those conflict styles." Excerpt 2*

The student's reflections display that CoC enriched their comprehension concerning conflict by presenting different strategies. The students also shared that their comprehension of addressing conflicts in teams has improved in terms of using broader methods and applying targeted conflict management strategies. This has led them to gain a more profound appreciation for the importance of mastering these strategies in resolving conflicts.

> *"It also taught me why or how different choices would affect the team and who should take which choices." Excerpt 3*

> *"All together I learned that there is no sure way to solve any conflict. Instead, it is a complex series of equations trying to factor in the needs of every member, and what resources are available to you." Excerpt 4*

The students' reflections suggest that the CoC session helped broaden their understanding of conflict origins, leading to the realisation that an issue might require more than one clear-cut solution. Recognising that there are various approaches to managing conflicts within teams has enriched their knowledge of the subject.

4.2 The Value of Diverse Perspectives and Collaborative Learning in Conflict Resolution Training

There are indications that the CoC had a permissive impression on the students' overall understanding of how to address conflicts within student projects. Their reflections emphasize the significance of participating in transparent group discussions and embracing collaborative learning environments when tackling conflict resolution. CoC also seems to have influenced the students' conceptions of skill development and knowledge acquisition concerning their peers. The participants expressed opinions that discussing the topic of conflict resolution with other individuals was beneficial as CoC forced them to take the perspective of the 'other'.

> *"What I probably learned the most from this experience might not have come from the game itself, but the people surrounding me. You often forget that people think differently than you, but that doesn't mean that only one way is the right way. It reminded me to be more mindful in how others perceive things." Excerpt 5*

The students also reflected on the importance of being introduced to group conflict and conflict management early when pursuing a project-based learning approach in game development courses. Likewise, they should be introduced to that communication and social interactions with project peers are valuable tools for dealing with project conflicts.

> *"It should be targeted at students who will be working a lot in teams and presented on a big screen in a big auditorium. This is because large group activities like this are more fun than working alone, and way more memorable." Excerpt 6*

Since the students, in retrospect, also played the game alone, they became aware of the value of group discussions and experiencing other persons' points of view.

"Playing on my own makes me realize how important an actual discussion with others is and seeing their perspective." Excerpt 7

> *"I feel like it is more effective in a group setting, if only because you can discuss the options with other people and get the pros and cons of each resolution style in a way the game itself does not provide. I do not get much out of playing it alone." Excerpt 8*

The excerpts highlight the students' attributed significance of transparent group discussions to gaining insight into others' viewpoints in the context of conflict resolution and personal growth. The Excerpt 7 emphasises the value of engaging in discussions with others, as it allows individuals to broaden their understanding by considering diverse perspectives. This reinforces the idea that interpersonal communication is crucial in enriching one's knowledge and fostering empathy towards the project's peers-viewpoints. Moreover, the Excerpt 8 reiterates the effectiveness of group settings in learning about conflict man magnet, as it enables participants to weigh the pros and cons of various resolution styles through collective discussions. The participant acknowledges that playing CoC alone provides different benefits, as it lacks the opportunity for meaningful dialogue and shared insights. This further underscores the importance of collaborative learning environments where individuals can benefit from their peers' collective wisdom and varied experiences.

5. Discussion

In this section, we delve into two themes that emerge from the Results in section 4 reflecting our findings in our theoretical foundation presented in Section 2, which encompasses Project-Based Learning, Conflict Management Strategies, and Serious Games for Conflict Management Training. We will explore these themes in the context of the theories and concepts discussed earlier, offering a comprehensive interpretation of their relevance and application. This will accumulate a broader understanding of how these ideas can be effectively implemented in real-world situations.

5.1 Raising Awareness Of Needs and Interests in Conflicts and Resolution Strategies

The participants' reflections align closely with Donohue and Kolt's (1992) definition of conflicts, illustrating that through the game, they became more aware of people's interdependence, who express diverse needs and interests, and experience interference from others in accomplishing their goals. Similarly, their reflections echo Algert et al. (2021), asserting that conflicts are essentially neutral, and the manner in which parties engage determines whether the conflict becomes constructive or destructive. Furthermore, the students' reflections also show similarities with Fisher, Ury, and Patton's (2011) framework, which emphasizes separating individuals from issues, concentrating on underlying interests instead of rigid positions, and generating creative options for mutual benefits.

The findings emphasize the significance of applying well-established conflict resolution principles to promote collaborative problem-solving and enhance understanding among individuals. This is indicated though the student’s reported impression of having a deeper comprehension of their peers' needs and interests through their participation in the CoC sessions. CoC appears to have played a role in this, as students engaged in group discussions to determine their course of action in the game. By moving beyond individual reflections, they discovered that different team members held unique interests and perspectives, thereby enriching their learning experience.

5.2 Conflict Resolution Skills Through Collaborative Gaming

Previous research has underscored the challenges in creating an artificial environment that is both authentic and engaging for students (Campos et al., 2012). In the case of CoC, using authentic scenarios that students recognized from their project-based learning courses led to group discussions in which all students actively participated. Employing authentic scenarios increased the relevance of the presented conflicts and the subsequent discussions, feedback, and solutions. Furthermore, our findings support Trepte et al. (2012) and Bartels et al. (2013) arguments concerning the benefits of games in providing safe environments for training students in conflict resolution through social interactions, collaboration, and iterative skill development.

The collaborative gameplay process stimulated heightened engagement and fostered more dynamic in-group and in-classroom discussions, resulting in deeper reflections upon review. This finding is consistent with previous research, which demonstrates that game-based learning with quick responses and immediate feedback enhances engagement and ultimately improves learning outcomes (Hilliard and Kargbo, 2017; Plass et al., 2016). Figure 2 illustrates how the game and the process seem to have contributed to the participants' engagement and learning outcomes.

5.3 Implications for Project-Based Learning

CoC can be used as a proactive approach to hindering possible growing conflicts in project-based teamwork and should therefore be implemented as part of the project-based courses. Using theory from the field of conflict management, the game teaches conflict management styles and gives a good foundation for in-depth discussions and increased understanding. Organising the learning environment as a game-based learning

environment, with participants in teams, seems beneficial to teach the topic of conflict management and can help improve the learning environment in general and hence the students' learning outcomes. As previous research shows, it is hard to simulate a conflict environment. This game adds to the toolbox of games that can facilitate pedagogical approaches to the matter.

6. Conclusion and Limitations

This study aimed to examine how game-based learning, using CoC as an example, impacts students' perceptions of managing conflicts in game development project courses. Analysis of the students' reflective notes suggests that CoC contributed to increased awareness and knowledge of conflicts in project-based learning and social interactions within student teams, fostering engagement and promoting more in-depth discussions and reflections.

CoC's design, featuring authentic conflict scenarios and prompt feedback and solutions, aligns with prior research on designing such games to enhance participant engagement and potential learning outcomes. It is essential to recognise that the same game may not yield the same level of engagement with different groups. The implementation process is crucial, and if the game is implemented differently, the experience may change, potentially resulting in less efficient engagement and learning outcomes. Consequently, adapting the game's implementation to the target audience is necessary.

There are several limitations to consider as well. A larger sample size would be beneficial to generalise the findings to a larger population. The study's findings may be context-specific and limited to the higher education institution and the game development course in question. Additionally, the participants' backgrounds as game development students and their personality traits (and gender) may have influenced their perspectives on using the CoC game. The game may not be as engaging or effective for other student groups, which could limit the generalizability of the findings. Lastly, self-report measures like the students' reflective notes may be prone to bias or errors.

7. Future Research

Based on our findings, we see various trajectories for further research. Further investigation into the effectiveness of CoC in conflict management education using randomised controlled trials or other experimental designs. Moreover, broadening the study's scope to include a more diverse array of participant populations, specifically individuals with differing levels of interest in games and prior knowledge in conflict management, offers an exciting prospect for continued investigation. Exploration of the long-term impact of CoC on students' conflict management skills by following up with participants after the game-based learning intervention has ended. Moreover, investigating the distinct mechanisms by which CoC enhances a sense of growth and heightened awareness of conflicts and conflict resolution skills, encompassing elements such as improved engagement, purposeful dialogues, and reflective thinking, would substantially contribute to the advancement of serious game research.

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Games-Based Learning in Business Management Programmes: A Reflective Analysis of Students' Experience

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Abstract: Games-based learning constitutes integrating games into learning experiences to create effective learning environments by applying some common characteristics which improve intrinsic and extrinsic motivation. Using an exploratory study design and reflexive thematic analysis, this paper shares insights from a research study conducted between September 2021-April 2023, to co-evaluate the effectiveness of a co-created games-based learning application, for formative assessment of learning on a business undergraduate programme. Potential benefits of games-based learning in higher education institutions (HEI) include introduction of a structured rewards system and goals in a fun and focused way into learning that can act as a powerful motivator to enhance engagement and promote participative interaction It offers an alternative opportunity to HEIs to redefine learner experience by re-evaluating contemporary pedagogies. Findings from this study indicate, application of games-based learning as a pedagogical intervention, can improve learning experience of students on business management programmes by allowing students to take ownership of learning. The co-created application piloted in this study, helped students to recall contents learned and track their performance through instant feedback received upon completion of a game. It also supported students in identifying weaknesses in their grasp of knowledge related to particular topics within a module and motivated them to work on areas of improvements. A key challenge identified by the students was expectation of a variety of games within GBL approaches to keep intrinsically motivated to use such applications for learning.

Keywords: Games-based learning, Gamification, Active learning, Gamified learning, Formative assessment

1. Introduction

The notion of Games-Based Learning (GBL) as an instructive approach is gaining traction in Higher Education as an 'enabler' of increased engagement and motivation through integration of gaming into learning experiences. GBL can be used to create effective learning environments by incorporating gaming characteristics that include making decisions and solving problems in increasingly difficult circumstances in complex environments The availability of digital tools and portable devices in recent years have proliferated the use of digital gaming as a mobile and social activity (Advance-HE, 2020). With blended learning becoming more prevalent, digital GBL is being seen by some researchers as a post-pandemic solution for higher education (Froehling, 2023). Digital games can be played remotely, making them accessible to students regardless of their location and can be played asynchronously, allowing students to learn at their own pace (Jackson, 2021). Application of GBL in business management education and its evaluation is not uncommon. However, there is relatively little scholarly attention paid to the involvement of higher education students in the testing and evaluation process of GBL applications designed and developed to support learning in business management programmes.

In this case study, the researchers aim to explore the concept of GBL from a gamification perspective using a co-created GBL application. Using a reflexive thematic analysis approach, the main objectives of this study are to explore students' overall experience of GBL in business management programmes and understand its effectiveness for formative assessment of learning by involving students in the evaluation process.

2. Context and Background

In general terms, GBL can be defined as 'learning that is facilitated by game' (Whitton, 2012). Also known as educational or serious games, GBL has gained significant attention as an innovative approach to engage and educate students in higher education. It is an active form of learning involving a variety of learning events such as instruction, assessment and feedback in addition to motivational events such as rewards and challenges (Braad et al., 2020). GBL is implemented in educational settings in various formats either by embedding learning contents seamlessly into the game itself in serious games or through use of gamified digital assessment tools that integrate gamification elements such as points, leadership board into quizzes and similar activities for practical pedagogical outcomes (Sad and Ozer, 2019). In the context of business management education, GBL refers to the use of games as a teaching method to support learning outcomes using a specific typology of serious games that combine simulations and games to support management and entrepreneurial training (Nonino, 2013). If applied as serious games, GBL incorporates principles of active and collaborative learning, intrinsic motivation, reflection and immediate feedback which collectively enables students to apply

knowledge and skills in relevant contexts while offering the opportunity to foster their metacognitive skills by assessing their own performance (Arnab et al., 2014).

Research into GBL have found benefits of applying this approach for learning in various contexts. For example, mobile learning games (MLG) has been found to be as effective as traditional textbook learning at transferring factual knowledge. The Entertainment Software Association (ESA) (2019) reported GBL for assessments (GBLA) to be a strong way of measuring implicit learning. A study by Lai et al. (2012) found that game-based cooperative learning can produce a better result by improving both students' learning and motivation (Vandercruysse, Vandewaetere and Clarebout, 2012) while supporting repetition, recognition and recalling of knowledge including collaborative learning approaches (Jisc, 2016). Additionally, a meta-analysis study by Karakoç et al. (2022), reported on wide-ranging effects of GBL on student achievement. Firstly, it promotes active learning by encouraging students to participate actively in the learning process, rather than passively receiving information. Secondly, games can provide a safe and controlled environment for students to experiment and make mistakes, facilitating deeper learning and understanding of complex concepts. Additionally, games-based learning can offer immediate feedback, personalized learning experiences, and opportunities for collaborative and competitive interactions among students, fostering a sense of achievement and social learning. Key benefits of GBL, include increased motivation, improved knowledge acquisition, enhanced problem-solving skills, and higher engagement levels among students. GBL has the potential to foster active and experiential learning experiences, enabling students to explore complex concepts in a simulated and interactive environment (Connolly et al., 2012).

2.1 Use of GBL for Formative Assessment of Learning

While there is a substantive body of literature that supports the educational benefits of GBL, limited work investigates the validity and generalizability of such systems for assessments. In discussing about Games-based assessments (GBA), Kim et al. (2022) argued that the use of digital games can be a powerful context to support student and assess student learning. GBL will be effective if it assesses learners while playing the game by providing detailed insights on the learning process, tracking motivational, emotional and metacognitive features to understand behaviour and final outcome, and immediate feedback based on embedded assessment to identify the areas of difficulties for learners to play the game (Ifenthaler et al., 2012). Research shows that bringing game-based assessments into classrooms can improve students' learning abilities by supporting the development of cognitive (e.g., memorisation, reasoning), Practical (e.g., time management, data handling), Motivational (e.g., confidence, immediate feedback) and social (e.g., collaboration and communication) skills (Ifenthaler et al., 2012; Vlachopoulos and Makri, 2017). It promotes learning that is fun while providing educators with real-time feedback to adjust lesson plans accordingly (Lin, 2019).

Although games can provide engaging and interactive experiences, there is a risk of superficial integration or misalignment with the curriculum. It is crucial to critically evaluate its implementation to ensure that game content is well-integrated with the curriculum, aligning with learning objectives, and promoting deep meaningful learning experiences. For instance, Squire (2011) highlights the importance of aligning game mechanics, narrative, and content with the desired learning outcomes. Simply adding game elements without clear connections to the course content may result in a lack of coherence and reduced effectiveness.

Another critical aspect of games-based learning in higher education is the assessment of student learning within game environments. Traditional assessment methods may not effectively capture the knowledge and skills gained through game-based learning experiences. Therefore, it becomes essential to develop appropriate assessment strategies that align with the nature of games and the desired learning outcomes. De Freitas and Oliver (2006) emphasize the need to go beyond traditional testing methods and explore alternative assessment approaches that capture the multifaceted learning experiences offered by games. These can include performance-based assessments, reflective journals, portfolios, or in-game assessments that measure the application of knowledge and skills within the game context. By utilizing a diverse range of assessment methods, educators can evaluate students' learning in a more comprehensive and authentic manner using a GBL approach (Petri and Von Wangenheim, 2016; Gris and Bengtson, 2021).

2.2 Involving Students in the Evaluation of GBL for Formative Assessments

There is currently a lack of literature where evidences of engaging students can be found during the process of product and service development, in this case a digital GBL application. The researchers applied the theory of co-creation (Dacre, Gkogkidis and Jenkins, 2018) to co-evaluate a pilot digital GBL application for joint value creation by improving the outcome of the design process. Nahar & Cross (2020) defined co-creation in the

context of involving students as partners in the creation of e-learning materials as a facilitator of digital literacy skills development in students and staff. The concept of co-creation with students stemmed from Healey et al.'s, (2014) student-staff partnership model, which explored this notion from the perspectives of engaging students in subject based research and enquiry, learning, design and development, curriculum design and pedagogic consultancy to enhance learning and teaching and student engagement. Involving students in the evaluation of the impact of games-based learning offers several benefits. Student involvement in the evaluation process can enhance their engagement and ownership of their learning experiences. When students actively participate in evaluating games-based learning, they become more invested in the assessment process and take greater responsibility for their own learning (Witton et al., 2020). By reflecting on their experiences, students can provide valuable insights into the strengths and weaknesses of games-based learning approaches.

Including students in the evaluation of games-based learning can provide unique insights into its effectiveness, engagement, and relevance. Students' perspectives can contribute to a more comprehensive understanding of the impact of games-based learning by offering qualitative data on their perceptions, challenges, and suggestions for improvement (Sicilia, 2015). Their perspectives can help identify aspects of the learning experience that may have been overlooked and shed light on the contextual factors that influence the effectiveness of games-based learning interventions providing opportunities for refinement, clarification, or additional support (Connolly et al., 2012). However, it is important to consider that student involvement in evaluation might not be feasible in all contexts. Students may feel the use of games for serious study as inappropriate or frivolous. Their perspectives are subjective and may not always align with educational objectives or long-term learning outcomes. Additionally limited time or resources, large class sizes, cultural barriers, accessibility or logistical challenges could hinder the choices around using games within curriculum (Jisc, 2016). Factors like these could affect the extent of student involvement in evaluation processes.

3. Methodology

A qualitative study design using exploratory method was applied in this research to explore undergraduate business students' experience of using a gamified approach to formative assessment of learning. Exploratory research is a recognised methodological approach in business research. It allows for an open-ended and flexible approach, enabling researchers to delve into new areas and gain a comprehensive understanding of the subject matter (Babbie, 2016). In the context of co-evaluating a digital games-based learning application, this approach can help identify and explore various aspects, including usability, engagement, learning outcomes, and student perspectives to enhance the validity and relevance of the evaluation results to ensure that the application aligns with the expectations and requirements of the target audience. Saunders et al. (2012) acknowledges that while exploratory method may not always yield definitive evidence, it still contributes to enhancing our understanding of a problem. Use of this method has been seen in previous research studies in the context of applying online gamification as an approach for positive enhancements in student engagement (Ding et al., 2018). Given the nature of this study, this method seemed to be an appropriate choice since it was important to consult learners during the evaluation process of a co-designed digital GBL application intended to be used as a gamified formative assessment tool.

3.1 Digital GBL Used and the Process of Application

The digital tool co-evaluated in this study is known as Ed Owl, a web-based learning application. Co-designed and developed between September 2021 and January 2022; Ed Owl was piloted on two final year undergraduate business management modules with finance specialism over a period of 8 months across two academic years. The purpose of the pilot was to introduce Ed Owl to the learners as a gamified formative assessment tool and use it synchronously or asynchronously to support learners in assessing their knowledge and grasp of topics following a lesson. 3 types of games: Quiz, Hangman and Match the definition were programmed in Ed Owl. Elements of gamification such as challenge and rewards were added to these games in the form of time restriction, points and badges. Students would log in to their Ed Owl account either at the beginning of a lesson or during a lesson to engage in playing Quiz or Hangman games to recap on topics or assess their level of understanding following the delivery of a topic. The contents of the games were aligned to their module learning outcomes and linked to summative coursework.

1.2 Data Collection and Analysis

Towards the end of the pilot phase, students from two taught modules on the undergraduate business management finance pathway programme, were invited to participate in a focus group. The focus group

consisted of open-ended questions to gather qualitative data around their perceptions of GBL as a learning approach, their experience of using Ed Owl as a facilitator GBL and formative assessment of learning on business programmes. A total of n= 14 students participated in two focus groups at two points in time between May 2022- April 2023. Findings were analysed using reflexive thematic analysis (RTA) technique. Byrne (2021) explained Braun and Clarke's (2012) approach of RTA as ''*an easily accessible and theoretically flexible interpretative approach to qualitative data analysis that facilitates the identification and analysis of patterns or themes in a given data set.*'' Using this technique, recurring patterns from participants' responses from the focus group have been arranged into three broad themes to constitute 'domain summaries' capturing participants thoughts in relation to a particular data collection question (Braun et al. 2019, p. 5 as cited in Byrne, 2021) as key discussion points residing within the data in a positivistic sense.

4. Findings and Discussion

4.1 Makes Learning fun, Social and Interactive

''Good thing about Ed Owl is it is fun to learn'' – Participant 4.

A key observation noticed from engagement with the GBL approach was the almost 'sudden transformation' of otherwise a low-key classroom environment into a fun and socially interactive atmosphere which resonates with some existing research findings about use of games for promoting a fun learning environment (Lin, 2019).Some of the students who were quiet by nature, were seen to exchange dialogues in an enthusiastic manner as participating in the games evoked a 'competitive' vibe among the students.

''It is an interactive and fun application especially by learning through games'' – Participant 2.

The challenges embedded within the games in addition to the points scoring system enabled with each gaming activity, may have induced this change in the students' behaviour and approach to formative assessment activities attempted. As students received immediate feedback following a game completion, it appeared 'intrinsic motivation' (Vandercruysse, Vandewaetere and Clarebout, 2012) to do better or out perform a fellow classmate encouraged students to attempt some assessment activities more than once in order to get a better score and self-validate comprehension of a certain topic being assessed has taken place. This observation reiterates GBL can foster opportunities for collaborative and competitive interactions among students, fostering a sense of achievement and social learning. The interactive nature of the GBL application increased students' motivation to learn which paved way for higher engagement levels among students (Connolly et al., 2012).

4.2 Enables to Recall and Retain Content

The students who participated in this evaluation had selected finance pathway in their final year business management undergraduate programme. There is a common fallacy among the students that the topics learned on this pathway are 'complex by nature' due to the context in which they are taught. Due to the diverse nature of the student population who join business management programmes at undergraduate level, not all students choosing finance pathway may have prior subject knowledge of some key concepts that are relevant to this pathway. As such there is a general apprehension in relation to some core concepts taught such as double entry book keeping, consolidation of financial statements, audit, risk assessment and control among others. The introduction of GBL approach has enabled the students in their opinion to ''learn and remember things''. The ability to get an answer 'right' and 'review' it through live feedback in the application has helped students to 'remember things' learnt.

''It is easy to understand topic that relates to the module through games, absolutely interesting!'' – Participant 3.

Student found their learning process to be more active (Karakoç et al., 2022) when using GBL approach. The opportunity to experiment and make mistakes in a safe and controlled gamified environment such as Ed Owl in this instance, collectively enabled students to apply knowledge and skills in relevant contexts to assess their implicit learning. It offered them the opportunity to foster their metacognitive skills by assessing their own performance (Arnab et al., 2014). Student found GBL approach supported them to reflect through immediate feedback generation thus facilitating deeper learning and understanding of complex concepts.

''It is good as it be always related to the topic we are studying'' – Participant 6.

What we learn in class we can put it in work and practice it on the web-based gaming application'- Participant 9.

Another important finding from the investigation, was the ability of GBL to foster improved knowledge acquisition and problem-solving skills among learners. As students could access Ed owl's digital games-based learning platform form any electronic device with internet connection, it allowed them to log in to the application and use it for asynchronously assessment of learning. The repetition feature within this application enabled students to develop their meta-cognitive skills in their abilities to recognise and recall (Jisc, 2016) knowledge to support meaningful contextualised assessment of learning (Ifenthaler et al., 2012; Vlachopoulos and Makri, 2017).

4.3 Increased Familiarity Leading to an Expectation for Variety

Frequent engagement with Ed Owl in their curricula meant that students became accustomed to the dynamic and diverse experiences offered by digital games.

> *''Need to give new games to keep learners entertained and as a mobile application feature'' – Participant 4.*

Incorporating a variety of GBL experiences (Petri and Von Wangenheim, 2016; Gris and Bengtson, 2021), can maintain interest and prevent monotony among learners with different game mechanics, challenges, and contents. However, meeting the expectation for variety can also pose challenges for educators and game developers. Creating a diverse range of GBL experiences requires significant resources, time, and expertise. Developing high-quality educational games with varied content and mechanics demands careful planning, content creation, and iterative design processes. Furthermore, ensuring that the games align with specific learning objectives adds another layer of complexity. The expectation for variety in digital games can create a potential risk of superficial or superficially diverse learning experiences. Adding variety without adequately addressing the core educational content and objectives can lead to a situation where learners are exposed to a variety of gamified learning experiences, but the depth of their understanding and retention of the educational content is compromised.

It is important to acknowledge that student perspectives are subjective and may not always align with educational objectives or long-term learning outcomes. Students' immediate enjoyment or perceived ease of use may influence their evaluation, which might not necessarily reflect the educational effectiveness of GBL. Therefore, a balance must be struck between valuing student perspectives and considering other objective measures of learning outcomes.

5. Conclusion

Findings from this study reaffirms, GBL can be an alternative effective approach for formative assessment of learning if applied in the context of business management programmes. The integration of student's reflections on their experience of using digital games for learning adds further value to the findings since students are the direct beneficiaries of any pedagogical interventions. This study has attempted to illuminate the importance of involving students in the evaluation process of digital GBL applications for learning during the design and development stage not only to allow ownership of learning but also to ensure joint value creation in the design process of such applications. Educators interested in applying GBL within a formative assessment of learning context should consider possible factors that affect how certain populations of students enjoy educational games, so it does not marginalize specific student populations and hinder their learning experience and academic outcomes. To strike a balance, educators and game developers need to consider the learning objectives and content as primary factors when designing game-based learning experiences. A thoughtful approach that combines diverse gameplay elements with solid pedagogical principles is necessary. Iterative design processes, user feedback, and research can help ensure that the variety in game-based learning experiences aligns with the intended learning outcomes.

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Collect That Coin: Efficacy Testing of Platformer Game Mechanics With Adult Learners

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Abstract: Digital serious games for adult learning have become a more prominent topic for research in recent years, yet platformer genre games for learning remain underexplored. Despite this, many adults enjoy platformer games for entertainment which presents the question of what about platformer games makes them less prominent in adult education learning games. Platformer games often focus on simple mechanics such as *collecting* and *race to the finish* which map well to lower-order learning but require more effort to map to higher-order learning. To address this case, we rapidly designed and developed a 2D platforming game prototype called *Biomes Rescue* for use in a large general-education undergraduate Geography course. The game follows an Indiana Jones-style character who collects and aligns items to different biomes by evaluating items collected. The problem follows the slime-like creatures: the enemy representing pollution that has impacted Earth's biomes. Three biomes have been disassembled by the enemies and the player must rescue all four biomes by critically thinking about the characteristics of each. We actively tested and adjusted *Biomes Rescue* over the last three years and focus this case on the latest implementation, which addresses the alignment of game mechanics to higher-order learning and Knowles principles of Andragogy combined with games-based learning. We hypothesized participants would have an unbalanced view of the dexterity-centered mechanics tied to fun more so than learning. Our mixed-methods exploratory study aims to understand what mechanics connect to fun and to learning from the learner's perspective using a quiz score - a newly added measure, and Likert scale ratings on Enjoyment with open-ended feedback. Data analysis consisted of thematic analysis and group differences on the quiz scores. This study holds implications for designing platformers for adult learners with an understanding of the differences in game mechanics application for engaging critical thinking.

Keywords: Game-based learning, Andragogy, Platformer games

1. Introduction

Games in adult education take many forms from board and card games to role-playing and strategy games. These game types and genres often provide complex systems of dynamics and mechanics that drive an alignment to higher-order thinking. However, other genres are less prominent in adult education, specifically platformers. Adult learners present unique challenges with games-based learning (GBL). The needs of adult learners often require focus on a variety of avenues to take and draw conclusions in a more self-directed manner (Merriam et al., 2017). As such, simple dynamics within a game such as a platformer game, remain an understudied genre within adult education. Limited studies on the use of platformers often focus on user experience and perceived learning with adult learners (Nasikun et al., 2017). Older studies on adults playing platformers for entertainment suggest the genre is popular (Zelinski & Reyes, 2009). In understanding that adults generally enjoy platformer games, it is unclear as to why they are not as prominent within adult GBL. We believe the underlying design of the platformer being driven by simple core dynamics such as *collecting* and *race to the finish* (Boller & Kapp, 2014) suggests the genre is suited for younger learners. Despite this, gameplay features like jumping, items, and enemies with a constant sense of challenge and frustration that impacts dexterity and visuospatial awareness are deemed enjoyable (Pedersen et al., 2009). Ultimately, the aforementioned mechanics map well to lower-order learning but require more effort to map to higher-order learning. The paucity of studies on the use of platformers with adult learners forms a need to understand the underlying nature of the genre and its implications for education.

Over the last three years, we created a prototype of *Biomes Rescue* using an iterative evaluation approach (Symborski et al., 2017). This case presents our third round of testing the game prototype at the University of Missouri in the United States. The game prototype, referred to henceforth as a game, assists undergraduate college students enrolled in an introductory geography course. The game's design requires students to identify key pieces of course content, relate the content to the game's goal, and demonstrate their resulting knowledge to proceed. Learning becomes essential to gameplay completion. Based on the intent of the game, we focused on understanding the role of platformer mechanics that relate to adult learning needs. The following sections

discuss adult learning with games and platformers and the design of the current version of *Biomes Rescue* with the mixed-methods study design. We conclude with points about student perceptions of game mechanics and the alignment with principles of adult learning.

2. Background

2.1 Adult Learning and Game-Based Learning Principles

Knowles' assumptions tell us that adult learners differ from younger learners (Dantus, 2021). Compared to younger learners, adult learners want independence or self-direction (self-concept) and the experience that they bring to the classroom (adult learner experience). Additionally, their desire to link their learning to what they can do with the knowledge they gain (readiness), their focus on how they can use the new knowledge to solve problems (orientation to learning), and their primary intrinsic motivation help differentiate adult learners from younger ones (motivation to learn) (Horsley, 2010). In his updated work, Knowles (1984) explained his four guiding principles for adult learners: 1) Involvement in instruction planning and evaluation, 2) Action-driven Experience with the ability to fail, 3) Relating to immediate needs, 4) Problem-oriented for greater transfer of knowledge.

Following the idea of a triadic worldview towards andragogy (Dantus, 2021), we view Knowles' principles through Games-Based Learning (GBL). More specifically, we combine the principles of andragogy with Gee's principles of empowered learning such as Co-design - where the player's involvement is active rather than passive. Similarly problem-solving through Well-Ordered Problems leads players through a problem rather than through content. Finally, in strategies, there is Meaning as Action where content and meaning are built into a problem to add to the relevance. (Gee, 2005).

2.2 Platformer Games

Platformer games - also known as *run and jump* games - present action through interaction with an avatar jumping and dropping around obstacles. Movement within a platformer game occurs in all directions (e.g. up, down, left, and right) compared to other genres that keep players on the ground and allow for movement along the X and Z axes (Pedersen et al., 2009). The typical platformer game often focuses on singular core dynamics to support the win state of a game such as race to the finish (e.g. racing against other players or time) or collecting (e.g. accumulating points, items, or power-ups) (Boller & Kapp, 2014). However, platformers can be more sophisticated in their design, incorporating puzzles that require combined cognitive development. For instance, jumping and landing onto specific platforms requires rapid processing speed alongside visuospatial planning that coordinates with a player's dexterity to execute a given task (Zelinski & Reyes, 2009). Incorporating learning into the action-heavy genre requires building on the strengths of such mechanics as collecting and puzzles.

3. Method and Materials

We rapidly designed and developed the third iteration of a 2D platforming game prototype called *Biomes Rescue* for use in a large general-education undergraduate geography course. The game follows an Indiana Jones-style character who must collect and align items to different biomes by evaluating the items' descriptions once collected. The game focuses on the first content covered within the undergraduate geography course, distinguishing biomes. This content assists students in identifying key characteristics (i.e., environmental controls) of different biomes to associate with cultural and environmental issues discussed later in the course. The context of the problem within the game incorporates representative slime-like creatures, sludglings. This enemy within the game loosely represents the pollution within Earth's biomes. Within this game, the player explores four biomes, where the sludglings have disassembled three of them. Players must reconstruct the three incomplete biomes by critically thinking about the characteristics of each to reassemble them while not being caught by the sludglings. Our current iteration of this game focuses on the alignment of game mechanics to higher-order learning and Knowles principles of Andragogy. Informed by earlier results, we hypothesized that participants would have an unbalanced view of the dexterity-centered mechanics tied to fun over learning.

3.1 Study Design

Our study uses a mixed-methods exploratory approach to establish connections between game mechanics to fun and learning (Creswell & Plano Clark, 2011). To conduct this study, we posed the following research question: How does a platformer engage learning in adult players? and the sub-question: How do adult players align platformer mechanics to learning?

Our framework driving the analysis and interpretation stems from an alignment of Gee's principles with Knowles's Principles of Adult Learning. The Allure Framework operationalizes Gee's principles as game mechanics that can be manipulated through the design of a game. This combination of mechanics within the Allure Framework connecting with the different Andragogy principles provides a framework for how adult learners perceive the impact of the game's mechanics on their learning.

3.1.1 Variables

We focused on using the simple and complex mechanics for game-based learning as categorized by the Allure Framework (Bisz & Mondelli, 2023) for the independent variable. These mechanics provide a way for students to interact with the learning content within the game. The two main complex mechanics behind *Biomes Rescue* are evaluating information to categorize it with *Classify the Pieces* and analyzing facts to find a similar relationship with *Concentration*. The key simple mechanic in both of these is *Random* as the players are presented with the information in a nonlinear way. For our dependent variable, we focused on learning outcomes from an external quiz question as well as a set of 5-point Likert Scale questions on Enjoyment.

3.2 Measures

To capture data for our research questions, we used a short survey and quiz. The survey collected basic demographics, a three-item set of Likert Scale questions on Enjoyment adapted from Davis (1989), and two open-ended questions. The enjoyment scale included items such as "I found viewing the interactive media on the Biome Rescue game fun" and had a moderate Cronbach's Alpha of 0.68. The quiz following gameplay consisted of three questions. Each question was rated eight points. The quiz tested students on their knowledge of biomes in general (Question 1) and knowledge about biomes within the game (Questions 2 and 3). Given that the students had received instruction on biomes in week 3, we designed the assessment to register both active recall of prior knowledge and new knowledge obtained through the gaming experience. Due to incompleteness, only questions one and two were included in the analysis. Our two open-ended questions asked students to indicate their likes and dislikes about the game and the potential for further development including improvements.

3.3 Participants

We recruited participants from enrollment in an introductory undergraduate world regional geography course taught each spring at the University of Missouri. There were 124 students enrolled in the course, of whom 21 were in the Honors section. 78 students enrolled as participants in the study through an informed consenting mechanism on the Canvas LMS and provided feedback on their game experience through an ungraded survey. Of the 78 students, we have freshmen (n=6), sophomores (n=26), juniors (n=21), seniors (n=25), and honors students (all levels) (n=18).

3.4 Game Mechanics

To capture data about the mechanics within the game prototype, we identified the key mechanics of the design and connected them to the Allure Framework's categorization of simple and complex mechanics for game-based learning (Bisz & Mondelli, 2023). This allowed the examination of student feedback across categories of mechanics to provide meaningful connections between learning and engagement.

Biomes Rescue incorporates the simple mechanic *Random* as the players collect and match clues to biomes in a nonlinear way. *Random* is a key component of the complex mechanics present, *Classify the Pieces* and *Concentration*. Specifically, the players collect key characteristics, or clues, dispersed across all four biomes, then evaluate which clues match each biome. Three of the biomes are incomplete, making some clues unavailable until others have been correctly placed. This requires players to move nonlinearly through the levels joined by the hub world.

The simple mechanic *Rival* occurs through the challenge of defeating the SludgeKing and his minions, and the dexterity challenge. In particular, the desert biome presents the highest level of challenge with the risk of falling into quicksand while dealing with sludglings. This *Role* associated with the player is that of Missouri Joe, a wildlife conservationist. The guiding narrative is built into the role, focusing on action within the game levels over deeper storytelling.

The most notable *Reward* is biome construction. Players must build the platforms in levels to progress through the game. The game rewards players by giving them more exploration of the biomes. Players receive instant feedback in the form of a pleasant "squish" sound when jumping on a sludgling and a coin collection sound when

collecting a clue. The player's character also blinks and loses hearts when encountering a sludgling without defeating it. Additional feedback includes earning points every time they defeat a sludgling. If the player squishes each sludgling exactly once and hits the SludgeKing three times to defeat him without restarting, the score adds up to a "perfect" 100 after winning the boss battle.

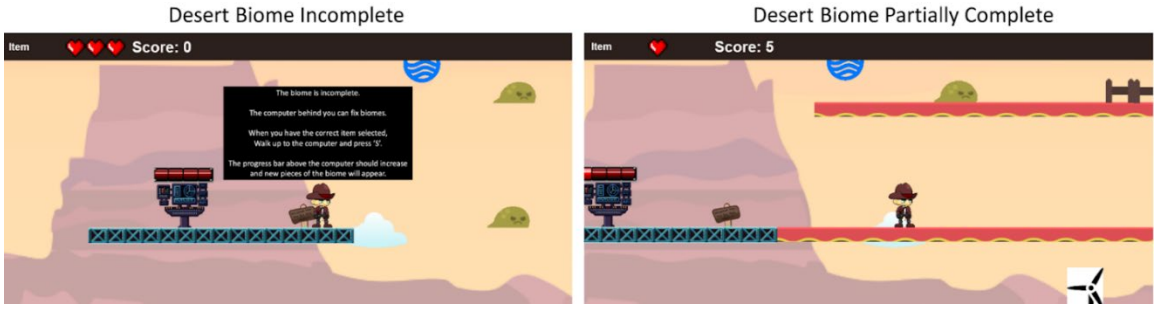


Figure 1: Example of Random and Reward mechanics in an incomplete biome

3.5 Procedure

The world regional geography course comprises 15 weeks of instruction with 50-minute lectures that meet twice a week. In week 12 of the 15-week course, the students were asked to bring their laptops to the lecture session and play *Biomes Rescue* for at least fifteen minutes at the beginning of class. The link to the game was embedded in the instructions for an ungraded survey in the Canvas LMS, which also included the informed consent document and the survey questions. After fifteen minutes passed, the instructor distributed a hard-copy quiz. Students were encouraged to keep playing the game before completing the quiz for an additional fifteen minutes or until they completed the game, whichever came first. After submitting the quiz, students were invited to take the voluntary feedback survey in Canvas. After class, the instructor graded the assessments and linked those scores to each student's survey results using a numerical identifier to preserve student anonymity.

3.6 Analysis Plan

To address our research questions, we incorporated a combined thematic analysis with non-parametric tests to confirm and detect relationships. Specifically, we open-coded using an Inductive and Deductive process (Fereday & Muir-Cochrane, 2006) to formulate two categories. Using Axial Coding on our two categories (Williams & Moser, 2019) along with a Fisher's Exact Test, we examined relationships between Adult Learning Assumptions and Game Mechanics discussed by the students. Significant Mechanics from the Fisher's Exact Test were put into a Mann-U Whitney test for our Learning Quiz Score and the variables from our Likert scale questions.

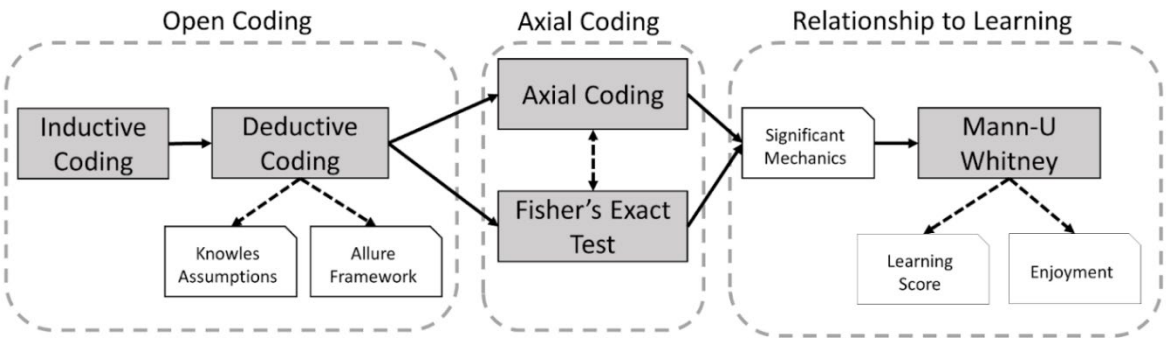
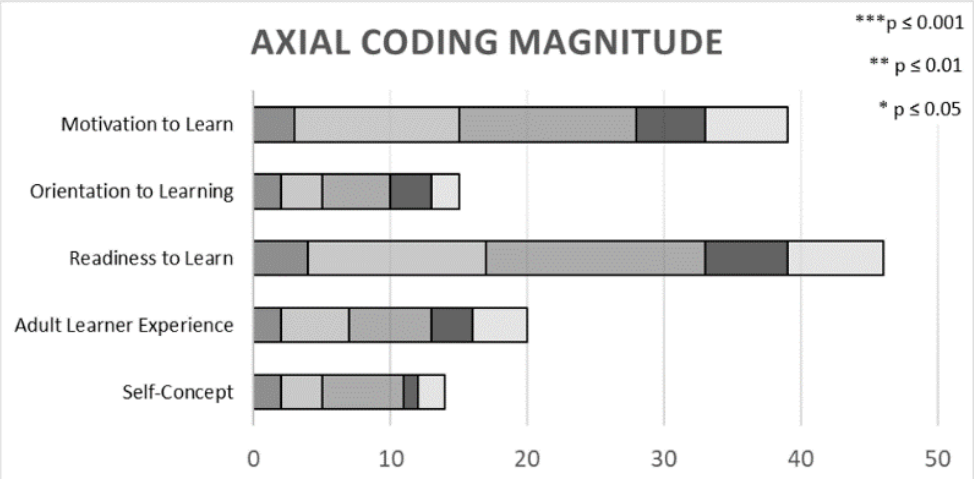


Figure 2: Analysis process for Mixed Methods Exploratory Approach.

4. Results

Overall, Biome Rescue was considered fun, engaging, and enjoyable. As one participant stated, it "was very fun and made me want to keep playing." The most commonly mentioned concern was the difficulty of the game. Many wished there was a way to regenerate lives or wanted checkpoints with a way to save the game so that they did not lose all progress after three chances. Participants mentioned the frustration they felt when they did not complete the challenge initially due to difficulty while others specifically mentioned enjoyment from the dexterity challenge.



	Self-Concept	Adult Learner Experience	Readiness to Learn	Orientation to Learning	Motivation to Learn
Role	2***	2***	4***	2	3**
Random	3***	5	13***	3***	12***
Rival	6**	6***	16	5*	13***
Reward	1	3***	6	3***	5***
Classify the Pieces	2***	4***	7**	2***	6***

Figure 3: Graph showing axial coding magnitude between game mechanics and Knowles Assumptions with supporting significant relationships identified using Fisher's Exact Test

Participant comments about the narrative, such as "it was charming," showed that they enjoyed the aspects of *Role* encountered in *Biomes Rescue*. While the participants enjoyed the *Role* present in the story, they also wished that the narrative more succinctly integrated the learning objectives of the game and conveyed more information about each biome. There was a desire to connect more with their previous experience in the course and have the narrative presented in a way that was more applicable to the game. In line with this sentiment, some participants called this a "missed opportunity," saying that the narrative should "[lay] out the goals of the game more explicitly" and that "more specific information about the biomes and objectives when entering the biomes would be helpful." Those who felt that the game did involve a connection with their previous experiences had positive comments about liking the platformer style, the game feeling nostalgic, and being relevant to them.

The aspects of *Rival* were pleasing to some participants. One participant stated, "I liked the difficulty added with the slimes and stuff, it did just enough to keep me on edge and enjoy the experience." Other participants commented variations of "it was fun stomping on the sludge monsters." Another participant said, "I liked the final boss fight at the end of the game." However, almost half of the participants wished the game was less frustrating, stating that the game was too difficult. For example, one participant stated, "I think it was a little unforgiving and difficult, because it was easy to die and it restarted the whole thing." Another participant stated, "The game was fun, but my biggest complaint is the fact you cannot get more lives, and that the quicksand one-shots you. It makes it very frustrating when you have to restart completely." Other participants were more direct about this complaint, saying, "the fact that there are no checkpoints was brutal, I'd like it more if you didn't go all the way back to the start when you died".

There were both positive and negative comments about the *Random* aspects of the game. Every *Classify the Pieces* comment was also coded as *Random*, but not every instance of *Random* mentioned involved *Classify the Pieces*. Some participants enjoyed the nonlinear progression of biome exploration, but many participants felt that the lack of direction on which biomes to enter and in what order "complicated" the game. This is often what participants were referring to when they indicated a desire for "more guidance" in the game, and was the most common complaint with a preference for pedagogical learning over andragogy. Somewhat contrary to Knowles' principle that adult learners desire independence and self-direction, more students wanted further guidance on where to go and what to do in what order than commented on enjoying the agency and exploration that the game provided. Two participants mentioned they would have preferred to play the game as homework so that they could take their time exploring and figuring things out on their own without the time constraints of the class session, indicating a preference for self-direction of gameplay.

Participants enjoyed the *Reward* aspects of the game, stating they liked the satisfying 'squish' sound when stomping on the Sludglings, the coin sounds when collecting the clues, and the emergence of the animals upon completing a biome. Others wanted there to be higher stakes and more incentive in the game. One participant stated, "It was really easy to cheat my way through by trying every item without really reading it. If I made an improvement it would be to have a consequence for every wrong guess." Similarly, others mentioned that "it needs to have more motivation for players in order to make a deeper impact" and "there needs to be more of an incentive to actually pay attention to the detail of the game." Finally, in line with Knowles' principle of intrinsic motivation for adult learners, many participants mentioned the game was immersive, engaging, fun, novel, and easy to play.

Participants liked the opportunities to problem-solve within the game and wanted more complexity with this type of learning, which coincides with Knowles' andragogy principle of focusing on how they can use newly acquired knowledge to solve problems. They seemed to enjoy the complex mechanic - *Classify the Pieces* the most. Their comments indicated that they wanted more of this type of learning in the game with more complex mechanics:

> *…be more effective than just explaining the biomes… something that enhances the information you're receiving… [allow] the lecture to cover the fundamentals and the game to enhance that knowledge… an engaging piece of information to pursue in a game… maybe you find an animal in the wrong biome and have to put it back where it belongs.*

These sentiments coincide with Knowles' principle of adult learners' desire to link learning to what they can do with the knowledge gained. The students wanted more utilization of learning within the game and more incentive to retain the information. One participant said, "I don't think the game engages with the topics enough though, and can be 'brute forced' by someone who just wants to rush through it." Along this principle of utilization, some stated they were unsure of their learning and wanted more from the game. "I didn't always feel like I was learning. I feel like there needs to be some type of quiz or mini game that would help you if you actually paid attention." Another participant stated the "teaching process is hidden in the game, and you can't see it obviously." This participant alluded to wanting the learning to be more overt. Another participant wanted there to be "some kind of worksheet to fill out while playing the game" to reinforce learning and provide access to content outside of the game. These participants wanted the concepts reinforced more, more formative assessment, and more depth to the learning.

Table 1: Mann-Whitney U Test Results on Quiz Score and Enjoyment by Game Mechanic. * indicates significance

Game Mechanic	Quiz Score	p-value	Enjoyment	p-value
Role	264.500	0.761	277.500	0.973
Rival	788.000	0.623	741.500	0.951
Reward	349.500	0.868	510.000	0.010*
Classify the Pieces	67.500	< 0.001*	436.000	0.456

Our Mann-Whitney U tests indicate that learning performance was impacted by the complex mechanic, *Classify the Pieces* while enjoyment was influenced by the simple mechanic, *Reward*, see Table 1. Each mechanic group was generated as a dichotomous variable where 0 represented students who did not indicate the specified mechanic and 1 indicated where comments aligned with the given mechanic. From the plots (see Figure 4), students who discussed aspects of Classify the Pieces performed better than students who did not recognize the complex mechanic. However, students who mentioned aspects of Reward rated enjoyment significantly lower than students who did not.

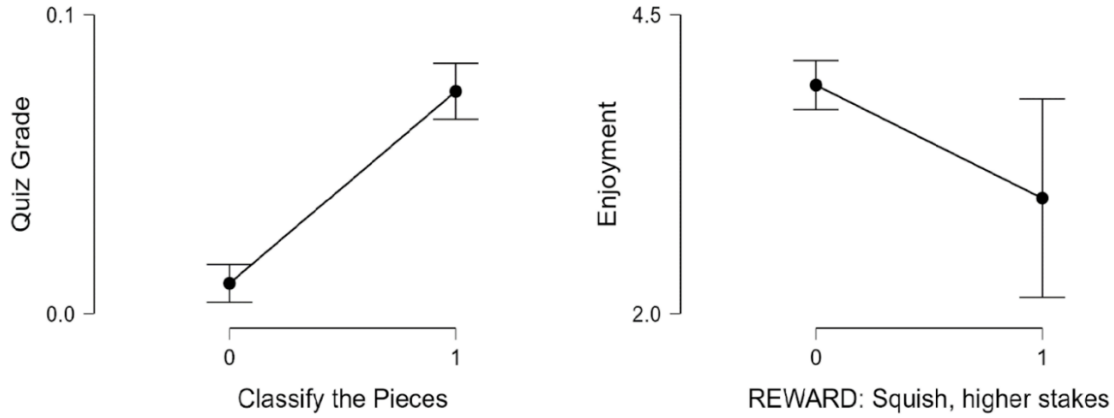


Figure 4: Mann-Whitney U test plots of Classify the Pieces on Quiz Grade and Reward on Enjoyment

5. Discussion

The notion that individual game mechanics could be recognized by adult learners as successful indicators of knowledge construction presents an interesting problem. Based on earlier studies, we hypothesized that enjoyment would connect to the mechanics instead of learning. So, we posed our research question to examine how players recognized mechanics and the relationship to Knowles principles. This relationship provides the basis for understanding learning and how it compares to enjoyment.

In the case of *Biomes Rescue*, the platformer genre game that built on previous years of design and feedback had incorporated complex mechanics with simple mechanics. The intersection of these mechanics seemingly created a more comprehensive way to utilize game mechanics as both an engaging portion of the game, but also as a higher-order assessment to evaluate the different pieces within each biome. This Classify the Pieces mechanic was preferred by adult learners which addresses Knowles principle of making learning problem-based.

How learners engage with learning changes as they age and transition to higher education, yet that transition may take longer in some individuals than others. As the course consists primarily of younger adults, some participants are still transitioning from pedagogy to andragogy. This is evidenced in the comments by the desire for more guidance over figuring out the game for themselves.

Our findings show that adult learners prefer more complex mechanics with higher-order learning. This aligns with Horsley's (2010) findings. Everyone seemed to enjoy *Role* and *Reward* and wanted more of these simple mechanics, but the complex mechanic, *Classify the Pieces,* was most preferred. As for *Random*, most students accepted the nonlinear nature of the biomes as part of the core game mechanic, but students still in transition from pedagogy wanted a more linear gaming experience. *Rival* was the most mentioned in the codes and the least popular due to the challenge presented by the platforming death conditions (Cuerdo & Melcer, 2020). This is likely because participants were frustrated by dexterity challenges not balancing with their platformer game skills. Specifically, player death where all hearts were lost meant starting completely over. We did not ask the participants to disclose their game skill level in the data, but novice gamers or those less experienced with platformer games would be frustrated by this type of challenge rather than delighted (Sun et al, 2018).

The game itself did not include *Rapid*, but this final simple mechanic was inadvertently added due to the time constraints of the class. This addition to the game through external implementation during the lecture period generated a limitation with our learning performance metric. Instead of counting all three questions within the quiz, only two were used. The nature of the two questions was dependent on how far into the game the student was able to get, leading several students to underperform on question two. This added time constraint interacted with the dexterity performance, leading to complaints of the challenge being too high. So, while adult learners are engaged with failure, there is a point when it becomes unenjoyable (Cuerdo & Melcer, 2020).

6. Conclusion

Though platformer games are not as common to adult learning, there is precedence for their use in higher education. As the paucity of studies on using platformer games for adult education drove us to conduct this study, we now have new questions to pose about the type of learning and impact of other gameplay features such as different ways to address challenge. When the design combines simple and complex mechanics, the

resulting engagement can achieve several notable aspects of adult learning. However, the expectation of guidance and overt assessment within a game presents an interesting challenge to align with both andragogical notions of self-guidance while also maintaining the distinction between games-based learning and gamification. Additionally, Knowles' theory of andragogy is relative and is not a one-size-fits-all approach when it comes to adults following the assumptions outlined by the andragogy model (Darden, 2014). Despite criticisms addressing the weaknesses of Knowles' theory of andragogy, the principles have been proven robust for teaching adults and are widely used by researchers today with the caveat that instructors must adapt this method to meet the needs of their diverse learner populations (Dantus, 2021). This leads to additional questions on how to align andragogy to other learning principles to address an increasingly diverse group of learners.

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Exploring In-Game Scaffolds for Higher-Order Learning in a Case-Based RPG Learning Game

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Abstract: As active learning tools, digital games often focus on including interface and design features to scaffold progression. However, little emphasis on the use of such in-game scaffolds for higher-order learning exists in the literature. We focused this study on the second interaction of a working prototype game called Stories of a GeoFarmer. The study evaluates the importance of in-game scaffolds for engaging learners in higher-order thinking in undergraduate Geography education. Stories of a GeoFarmer is a case-based role-playing game where players take on the role of a farmer in different countries. The game utilizes documented case studies of different environmental issues relating to cultural geography to place players into the role of the individuals impacted by the various situations. The situations are ill-structured presenting interesting arguments for no-win situations meant to engage more thinking about geographic implications. We incorporated several in-game scaffold types that connected to the learning objectives including metacognitive, conceptual, and procedural. We use a mixed methods exploratory design approach consisting of thematic analysis and correlation of post-game survey responses. Our research question asks how does in-game scaffolding in the geography game Stories of GeoFarmer affect the adult learners' experience? Results from 63 undergraduates indicate that students can regularly recall and extrapolate how their in-game actions affect the environment. However, fewer students are able to evaluate why no singular solution exists to the game's problem despite all the provided in-game scaffolds. Metacognitive scaffolds play the largest role in prompting students to recognize cause and effect but also highlight the necessity of making multiple scaffold types more prominent in order to reach higher-order thinking. This study holds implications for serious game designers to consider how in-game scaffolds can be presented to support high-order learning in adults.

Keywords: Games-Based learning, Role-Playing games, Case-Based learning, Scaffolding, Adult learning

1. Background

In education, there is a need to utilize academic curricula, lesson plans, activities, experiences, discussion topics, etc., that challenge students to solve complex and irregular problems due to their prevalence in the 21st-century professional landscape. Providing students more opportunities to encounter situations where higher-order thinking is necessary to resolve these problems is a challenge for almost every academic professional, and many have started implementing Game-Based Learning (GBL) to meet this need. GBL is a transformative pragmatic approach that can create unique digital learning environments that support higher-order thinking skill development (Jan and Gaydos, 2016, p. 6). Specifically, GBL defines games that situate players in purposely designed environments, in which the player must become a proactive learner who gains the higher-order problem-solving skills necessary to overcome the game's built-in challenges (Jan and Gaydos, 2016, p. 10). GBL environments, if properly designed, have been viewed as a potential way to provide student's consistent experiences where they interact with problems that prompt continual growth of their problem-solving skills throughout the entire game that can be transferred inside or outside their original gameplay experience (Gee, 2005, p. 9).

1.1 Active Learning and Andragogy

To understand the needs of adult learners and how active learning can and should be applied within a game context, we look to Knowles theory of andragogy. The investigation into adult learning with serious games primarily focuses on the understanding that the design of the game can be made to align with adult learning

theory (Symborski et al, 2014). In an active learning environment, learners engage problem-solving through activity (Lewis and Bryan, 2021). This active engagement with higher-order problems connects with the ability to explore while assuming responsibility for one's own learning – the foundation of adult learning (El-Amin, 2020). The focus on active learning within andragogy within our study examines the principles presented by Knowles and how we combine them with GBL principles from Gee (2005). Gee's principles of good game design dovetail with active learning, providing overlap with Knowle's andragogy. Specifically, problem-solving in games where the presentation of information and the structure of a larger problem can be scaffolded for players to associate to the larger game goal. This type of connection between active learning in games connecting to goal-driven needs of adult learners illustrates a need for understanding how scaffolding assists with adult learning.

1.2 Scaffolding in Games

GBL treats games as whole learning systems, meaning that learning can and often is scaffolded in a similar manner to other learning systems to support feedback (Melero, Hernández-Leo and Blat, 2011). Scaffolding offers information that can be *just in time* (Gee, 2005) or structured following performance in an activity. In GBL, the nature of scaffolding can vary from clues to reflections external to the game (Melero, Hernández-Leo and Blat, 2011). However, when learning must happen within the closed system of a game, there is a need to categorize different game elements into aligning scaffolds. Cai et al (2022) noted that more work needs to be done understanding scaffolding mechanisms and the nature of the influence they have on both behavior and learning, especially in adult learners who need to connect learning to a problem (El-Amin, 2020).

We explored several scaffolding types in a working prototype of the digital learning game, *Stories of a GeoFarmer*. There were three main scaffolding types we used in this study. The first type is conceptual scaffolding. This specific scaffold uses concept mapping and/or specific tools to help students engage in visualization depicting concepts so they can identify what to think about when solving a problem (Kim, Belland and Walker, 2018, p. 402). Metacognitive scaffolding has students reflect on what they are learning along with how they learned it and encourages them to think deeper about the problem at hand in order to find solutions (Kim, Belland and Walker, 2018, p. 402). Procedural scaffolding helps learners understand specific rules to the game/activity, steps to take, and the progress the student has made up to a given point (Chen, Hou and Wu, 2023, p. 5). We included elements of strategic scaffolds in our procedural scaffold as well. Strategic scaffolds help students identify and process information presented to them and help them develop a solution to the presented problem (Kim, Belland and Walker, 2018, p. 402). Procedural scaffolds fit into our game much more effectively than strategic did, though elements of strategic scaffolds were still applicable to the scaffold we implemented. The focus on these specific scaffold types connecting to active learning among adult learners led us to ask two research questions: 1) how does in-game scaffolding in the geography game *Stories of GeoFarmer* affect adult learners' experience? And, 2) how does in-game scaffolding in the geography game *Stories of GeoFarmer* affect the adult learners' perception of learning?

2. Methods

This study used an exploratory mixed methods design approach (Creswell and Plano Clark, 2017) to better understand the adult learner's experience with in-game scaffolding in a GBL environment. Such a design, we believed, would allow for stronger correlations to be made between the adult learners' experience with the implemented scaffolds and the attainment of the higher-order learning objectives of the GBL environment. The study's qualitative research question was how does in-game scaffolding in the geography game *Stories of GeoFarmer* affect adult learners' experience? Which was supported by the quantitative research question of how does in-game scaffolding in the geography game *Stories of GeoFarmer* affect the adult learners' perception of learning?

2.1 Game Description

Stories of a GeoFarmer is a role-playing game (RPG) focused on teaching undergraduate geography students about sustainable agroforestry and its socioeconomic impact in south and east Asia (Figure 1). The game was created using the RPG Maker MV game engine and utilized built-in assets, third-party graphics, and custom-made sprites. Players progress through levels by completing a series of quests from non-playable characters (NPCs) and are forced to make decisions that balance the economic, environmental, and social impact on the region. As players complete quests, they obtain the in-game currency, Ringgits, as well as items that help them advance through levels faster. This iteration of the game includes a significantly updated tutorial, brand-new farming, and logging mechanics, a heads-up display (HUD) for quest and progress tracking, and a revised story

with new maps. The tutorial begins with the basic movement and selection mechanics of the game and returns throughout the game as more advanced mechanics are introduced. An NPC provides dialogue instructions and even demonstrates some of the actions the player will need to complete within the tutorial. Regarding new features, the farming and logging mechanics utilize advanced event scripting and JavaScript to include collision tracking that registers player tool collision per farm plot or per tree. The heads-up display shows the progress of quests in each area, keyboard controls for the logging and farming mechanics, and two meters that track progress. The envirometer measures the player's effect on the environment and the populameter measures the player's popularity with the in-game characters based on the choices made in the game. Along with the mechanics and user interface updates, the story and maps were updated to align with these changes. The story follows a farmer whose property was destroyed due to climate change and who is trying to work to secure a new homestead and source of income. These updates were implemented over the course of a semester and were made with assistance from a number of contributors that helped with the story, dialogue, learning objectives, and overall game design.

Figure 1: Scenes from Stories of a GeoFarmer, including the title screen, tutorial, and NPC interactions

Three primary scaffold types were selected: metacognitive, procedural, and conceptual, see Figure 2. Each scaffold type was represented through an aspect of the game. The metacognitive scaffold was the combined user interface meters, envirometer and populameter. The procedural scaffolds were based on NPC guidance along with the tutorial (Chen, Law and Huang, 2019). Lastly, the conceptual scaffold was Wong Enterprise signage that appeared in areas taken over by the company. This final scaffold would multiply across the game environment as the player sided with the company over the indigenous people.

Figure 2: Scaffolds represented in the game with the metacognitive scaffold on the far left, the conceptual signage to the right of the metacognitive meters, and the procedural scaffold as NPC interaction

2.2 Participants

Participants in the study were recruited from the 124 students enrolled in the Regions and Nations course. Twenty-one (21) students were enrolled in the Honors section, and 103 in the regular section. The Honors and regular sections meet for lecture twice a week, and Stories of a GeoFarmer was implemented and tested in lecture during week 5 of the 15-week semester. Apart from the midterm and final, each week in lecture culminates in a timed 5-point quiz the students take on the Canvas LMS. For week five, students were given the option to “play-test” Stories of a GeoFarmer or take the scheduled quiz for the week.

Sixty-three (63) of the 124 students opted to play-test the game: 10 freshmen, 20 sophomores, 13 juniors, and 20 seniors. For point of comparison, total enrollment in the course consisted of 18 freshmen, 33 sophomores, 36 juniors, and 37 seniors. Of the 63 participants, ten were enrolled in the Honors section, and 53 in the regular section. For point of comparison, total enrollment in the course consisted of 21 Honors students and 103 students in the regular section.

2.3 Procedure

The course instructor created an ungraded Survey in Canvas with the Institutional Review Board (IRB) informed consent along with instructions asking the students who volunteered to play the game all the way through

until receiving their "score card" in the treasure chest at the "final farm," which marks the end of the game in the prototype. Clicking "play" constituted agreement to participate in the study and linked them directly to the game's start screen. Once the students completed the game, they were required to take and upload a screenshot of their scorecard and complete the feedback survey to earn five points. All 63 participants successfully completed the requirements. The survey consisted of 15 Likert-scale questions about Enjoyment (adapted from Davis, 1989), Usefulness, Guidance, and Perceived Learning. Additionally, there were six open-ended questions to follow up on in-game performance and opinions towards the use of the game in the course (e.g. Review your environmeter and populameter scores, what is your opinion on the results of your scorecard?).

To analyze the study's qualitative research question, thematic analysis (Braun and Clarke, 2006) was conducted on the responses collected from the surveys submitted after participants finished their run-through of *Stories of GeoFarmer*. Specifically, we adopted the Collaborative Qualitative Analysis approach (Richards and Hemphill, 2018) where we utilized a consensus coding approach through six group meetings across three weeks. The first two rounds of coding focused on a combination of inductive and deductive coding to form and test our codebook (Fereday and Muir-Cochrane, 2006). The final round of coding consisted of a group axial coding conducted by the same three coders in a singular collaborative session to further develop potential combinations between the data (Williams and Moser, 2019). The aim of the consensus coding was to add trustworthiness to the independent coding conducted outside of the group meetings. All coding was performed using Delve's qualitative data analysis software. We then conducted a correlation analysis using JASP across the themes using Fisher's Exact Test to identify relationships among the themes. Significant themes were then related to four variables from the survey: Enjoyment, Usefulness, Guidance, and Perceived Learning.

3. Results

After conducting the thematic analysis of the survey data and holding a collaborative discussion, five themes were derived from the data; NPC, environment, ethics, conforming, and game dilemma. These themes will be defined and given in-game context in the following paragraphs.

Table 1: Thematic Code Book with Code Count Results.

Theme name	Code count	Theme description
NPC	24	Participants list and/or describe in-game interactions with the game's NPCs and how those interactions made them realize their actions impacted the environment.
Environment	75	Participants list and/or describe in-game actions they did that impacted the environment, whether positive or negative.
Ethics	38	Participants list and/or describe in-game actions that could be perceived as immoral or based on ethics that led to environmentally harmful events.
Conforming	14	Participants recognized and/or described in-game moments where they conformed to the demands of Wong Enterprise, which negatively impacted the environment.
Game Dilemma	12	Participants recognized and/or described how their in-game situation was challenging, specifically how their characters faced an ill-structured problem with no clear solution.

The theme "NPC" (standing for non-playable character) was used to identify when students noted the procedural scaffold in the game. Specifically, it was used when the student noted an NPC interaction made them realize their effect on the environment. This could be both a positive or negative effect on the environment. For example, one student talked about how someone working for Wong Enterprises asked them to burn down a section of the forest to clear it. Another student mentioned that negotiating on behalf of the

locals with Wong Enterprises at the end of the game opened their eyes to the environmental implications of the deal they were negotiating.

The theme of "environment" is made up of two significant observations of the data. First, students across the dataset could consistently list or describe in-game actions that harmed the environment. I.E., burning a section of forest, cutting down trees, or planting palm oil trees. Specifically, students were able to correlate how these negative actions impacted their envirometer and populameter. The second observation within this theme was that students could also list or describe in-game actions that supported the environment. I.E., planting the correct tree or refusing to burn a forest section down. Specifically, students also correlated how said actions impacted their envirometer and populameter. Moreover, the implemented metacognitive meter scaffolds and their connection to in-game actions were present throughout the entire dataset.

When coding for the theme “Ethics”, we were looking for any mention of a poor ethics or actions that could be perceived as immoral that led to a negative environmental impact. Examples of these actions would be taking bribes from Wong Enterprises, lying for them to cover their tracks, or anything that seems morally wrong to do. One student wrote “I really realized that the decisions I was making were wrong at the end when the elders and family members were speaking and the corporation was trying to bribe me.” Students connected these poor ethics with both the metacognitive (meters) and the procedural (NPC interactions) scaffolds. They noted that the specific interactions with multiple NPC’s assisted them in realizing these morally wrong actions they were taking. Furthermore, the changes of the meter scores after they took the morally wrong actions aided in them realizing the actions effects on the environment and the people surrounding them.

The theme “Conforming” was used to identify when students took actions in the game to align themselves with Wong Enterprises, whether they knew it was morally wrong or not. An example of this would be when one student said, “If I folded to the big business and their greediness my populameter would have risen while the environmeter would of gone down.” Students most often associated the metacognitive scaffold with this theme. They noted that conforming to the desires of Wong Enterprises (such as exploiting the environment, brokering one-sided deals, etc.) would increase their popularity score, but decrease their environmental score. Additionally, NPC interactions (the procedural scaffold) with people such as Wong Enterprise representatives and village leaders showed the students the effects of their actions when they conformed. This means the students were able to recognize their actions when conforming to the interest of Wong Enterprise directly effected both the metacognitive and procedural scaffolds. However, they were not able to correlate these actions with the overall learning goal of the game.

The theme "game dilemma" is centered around the instances in which students identified the main high-order learning objective of the game, which is that their in-game situation was challenging and was an ill-structured problem with no clear solution. An example of a student response coded in this theme was, "I did not like how it felt like there was no way to win because both of my meters kept going down until about halfway through the game." This particular student was able to recognize the main learning objective of the game due in part to their interaction with implemented metacognitive meters and the procedural NPC scaffolds. The conclusion was drawn after analyzing these students' survey responses that connect their experience with the scaffolds and their understanding of the main learning objective, a pattern shared amongst the other codes in this theme.

Based on the qualitative themes, we conducted a correlational analysis of the themes. Using Fishers Exact Test, we found that Game Dilemma related to several of the other codes based on students who identified aspects related to NPC interactions, Environmental Impacts, and Conforming to Wong Enterprises, see Table 2.

Table 2: Fishers Exact Test Results Showing Relationships amongst Theme to Game Dilemma. **significant

	Log Odds Ratio	P
NPC	-1.120	<0.001**
Environment	0.417	0.008**
Ethics	-0.067	0.651
Conforming	0.828	<0.001**

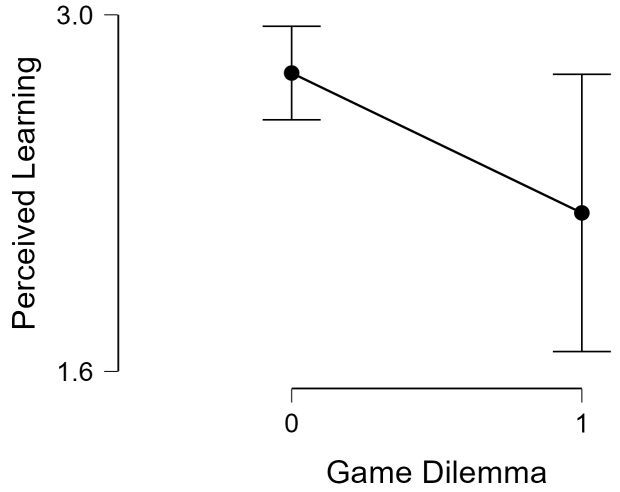

Figure 3: Plot showing relationship between student self-efficacy (through Perceived Learning) to identifying the Game Dilemma

Lastly, we completed a Mann-Whitney U Test on students who identified the Game Dilemma to see if there was a relationship to their perception of learning within the game. A significant difference ($U=348.000$, $p<0.05$) was found between students who identified the Game Dilemma and those who did not when they rated their self-efficacy towards learning. Additional tests were checked for Enjoyment, Perceived Guidance, and Perceived Usefulness, however, none were significant.

4. Discussion

4.1 Metacognitive Scaffolds

The importance of in-game scaffolding for learning also reveals the issues with different types of scaffolds. Learner attention in an exploratory space can easily shift focus to where feedback is most prominent, or with adult learners focusing on what appears most relevant. With metacognitive scaffolds built into the user interface of the game, students fixated on the scaffold, forcing it to become the primary goal of playing. This led to fewer students achieving the learning objective, to realize the ill-structured nature of the problem, the *Game Dilemma*. The intention of the metacognitive scaffold was to indicate player performance through each action. At the level of actions carried out by the players, the relationship was partially well understood. However, without attention being directed towards other features within the game, the nature of the problem became less evident. This idea that scaffolding distracted from the game, or another aspect of the game was similarly found in the study conducted by Charsky and Ressler (2011). In their study, the use of an external concept map to play the game took precedent over playing the game, resulting in lower posttest scores.

4.2 Conceptual Scaffolds

Conceptual knowledge is the foundation to generating higher-order activities, yet scaffolds representing such changes should be more overt to avoid being overshadowed within a game environment. The singular conceptual scaffold of signage proved to be too passive for learners to recall in their reporting. While in the gameplay session, the scaffold may have been used to indicate based on player actions involving Wong Industries that the company was slowly taking over. However, students were unable to recognize this scaffold in their recall of the complex situation they faced. Passive scaffolding serves many purposes to provide simple yet visual cues like signs for navigation. However, within a system like a game, players may lose the need for simple cues (Ding et al, 2009) while they are directed to complete quests and explore with purpose.

4.3 Procedural Scaffolds

Learning the rules of a system through procedural guidance is necessary in any learning system. While very prominent, procedural scaffolds became supports for the metacognitive scaffolds. The direction from NPCs and pop-up indicators along with a tutorial level that embedded the narrative goals created a unique challenge for the students. In switching focus to filling out the two meters, the actions guided by different NPCs within the game became more important in establishing an individual way to progress in the game. Strategic or procedural scaffolds are important in assisting metacognitive scaffolds with learner guidance and self-planning

within board games (Hou, 2022) which suggests that the reduced role the procedural scaffolds had within the data may follow a similar need in digital games.

4.4 Achieving Learning

Learning with the various scaffolds designed into the game was achieved in parts. The larger learning objective, to develop an understanding of the ill-structured nature of the problem faced by farmers, was not solvable with a single solution. While fewer students were able to identify this dilemma, the ones who did scored their perception of learning lower than their peers who were not successful in recognizing the learning objective. This suggests that engaging with the problem presented in game may be dependent on the scaffolds. Specifically, the choice of scaffolding types to incorporate could play a large role as passive or static type scaffolds have indicated mixed results over the more adaptable scaffold types (Chen and Law, 2016). The decision to select scaffolds associated with knowledge types (e.g. metacognitive, conceptual, and procedural) provided potentially too many similar options for the problem. Though Chen and Law (2016) were successful in blending the more adaptable to static scaffolds, the type of game and learner age group may also be a consideration when the focus is on engagement with a higher-order problem.

5. Conclusion

Scaffolding is fundamental to active learning environments and comes in many forms. For GBL, it is necessary to consider the type of scaffolds incorporated to avoid confusion and keeping students from feeling outside of the structuring of their learning. The second iteration of Stories of GeoFarmer illustrated unique challenges in the use of in-game scaffolds. Learner attention as well as meaningfully situating when a game occurs play a large role in the success of performance for higher-order objectives. Future work needs to be done on better understanding the nuances of different in-game scaffold types and what external factors may play a role in diminishing the intended effect.

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Proposal for a Participatory Methodology for the Creation of Serious Games

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Abstract: We are facing a new generation of students, who are not only looking for theoretical knowledge, but also want learning to be practical, interesting, and fun. They request didactic techniques that allow them to have a more prominent role in their learning, models that are not focused on teaching, but on learning. They are students with different characteristics because they were born in the digital age. Technology has changed the way they relate to the world. They are not comfortable with respect to traditional models and try to incorporate new technologies into all aspects of their lives. Within the educational field, new technologies are seen as a tool that facilitates learning and develops skills in students. From this perspective, the development of simulators and serious games are now used as a strategy to facilitate learning. The advantages of using a serious game seem evident, they help develop critical thinking, encourage creativity, increase problem-solving skills, increase retention, among other benefits. However, when games are not well designed, they lose both their appeal and their playful essence. One reason for these problems is the absence of the application of any design methodology, and that many of these problems come from the requirements definition phase. Specifically, most of the problems occur in the game design phase, where there is a deficiency in the writing of the requirements requested by the teachers. When the requirements are vague, or ambiguous, experts in the development area are unable to interpret the interaction design, the game mechanics, or the way in which users will interact with the software. This article aims to discuss the specifications and requirements that instructional designers and developers should address before migrating to project development, implementation, or evaluation. This article is important because it analyzes the need to establish clear requirements and objectives that will facilitate the creation of serious games in education.

Keywords: Serious games, Higher education, Educational innovation, Game-Based learning, Simulators, Virtual learning

1. Introduction

In recent years we have been experiencing a technological revolution that has changed our lifestyles and modifies our paradigms. Social networks, cloud computing, automation, artificial intelligence, IoT, are some of the information and communication technologies that have transformed our way of perceiving the world. These innovations have transformed the paradigms of societies, changed the skills and competencies demanded by employers, and renovated the way knowledge is created, transmitted, and assimilated. In addition, the younger generations have different characteristics. On the one hand, they are digital natives, and they feel more comfortable with the use of technology (Monaco and Martin, 2007); and on the other hand, they prefer to have a more prominent role in their learning. Methodologies that only allow information transfer in one direction make them uncomfortable (Kiili, 2005).

Within the educational field, Information and Communication Technologies (ICTs) are seen as tools that can promote learning opportunities and develop skills in students (Gros, 2016). Many examples of the use of ICTs can be observed in educational platforms and virtual environments. Specifically, the use of Serious Games (SGs) and simulators has been one of the preferred options for students in the classroom, it has been shown that the participation of learners in these games generates changes in their attitudes, beliefs, or behaviours (Tilvawala, 2019). From this perspective, SGs are now used as a strategy to support learning. Different areas of study use this resource, medicine (Graafland, Schraagen and Schijven, 2012), logistics (Pacheco-Velazquez and Aguilar-Avalo, 2019), military training (Samčović, 2018), nursing (Tan, Lau and Liaw, 2017), among others.

One of its great advantages of using SGs is the creation of motivational factors that have significant learning for students (Naul and Liu, 2020) (Meij, Veldkamp and Leemkuil, 2020). On the other hand, there are authors who affirm that SGs help students to develop critical thinking skills (Madani, Pierce and Mirchi, 2017), improve retention (Bergeron, 2008), increase creativity (Riedel & Hauge, 2011), develop problem-solving skills and decision making (Pacheco-Velazquez, 2022).

Although the benefits of playing serious games seem obvious, not all serious games work the same way. Some researchers claim that games that are not well designed lose both their appeal and their playful essence (Ravyse et al., 2017). Some studies point out that this happens because not all serious games are the result of applying some design methodology, and that many of these problems come from the requirements definition phase (Carrion et al., 2017). Taking care of the design phase in the creation of a serious game is one of the most important points that developers and academics should consider. This stage is fundamental because the characteristics of the game, the interaction of the players, the learning objectives, and the creation of the databases are defined in it.

This article aims to establish the steps that must be followed to achieve an efficient development design for serious games and achieve the purposes for which they have been designed.

2. Literature Review

A general statement is that people love to play games. A game is represented by a set of rules that establish norms for the interaction and behavior of the players and offer an identifiable result. With the new technological trends, digital games have achieved enormous success. It is not just about the graphic elements, most of the successful games also have sophisticated design methodologies that emotionally engage the players (Lugrin et al., 2013).

The definition of a SGs is a digital game created with the intention to entertain and to achieve at least one additional goal (e.g., learning or health) (Dörner et al., 2016). This type of game has objectives that are beyond the playful element, if in addition to being fun and entertaining, they must also provide teaching, then we are talking about educational games. Carrion et al. (2017) points out that many serious games are not well designed in their initial phase, and at the end of the project, teachers and developers realize that the game does not meet the pedagogical objectives, they add that although there are a series of methodologies specifics for videogames, the number of methodologies proposed for the design of SGs is limited.

Nadalski et al. (2008) describe a five-phase methodology for developing serious games which they call EMERGO. In the first phase, the designers present the idea of the game. This phase is important since it establishes the context, the content, the use of media, and the pedagogical objectives. In the design phase, designers must specify the mechanics of the game. Then follows the development stage, where programmers must do the work. In the implementation phase, instructors and students enter the game portal to test the game. Finally, the evaluation phase measures whether the game satisfies the specifications described in the analysis phase (See Fig. 1) (Nadolski et al., 2008).

Figure 1: EMERGO Methodology Model

Marfisi-Schottman (2012) presents a methodology composed of seven phases which he calls LEGADEE (Learning Game Design Environment) (see Fig. 2). In this methodology, the first two phases are dedicated to listening to the customer's needs and establishing the specifications and requirements of the game. In the third phase, academics and developers jointly describe the learning scenarios in the game.

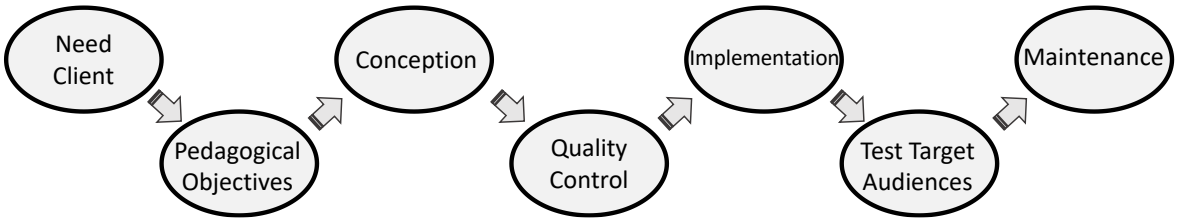

Figure 2: LEGADEE Methodology Model

Barbosa et al. (2014) propose a new methodology for the creation of a serious game. They suggest only three stages: The History of the Game, Main Game, and Learning Mechanisms. For the authors, the design must contain a story that introduces the game. The game contains different scenarios, and in each scenario, players must overcome various challenges. To overcome these challenges, players must put various knowledge into practice (Barbosa et al., 2014). The proposal of this methodology is reduced. The authors suggest incorporating

scenarios and a set of challenges in each scenario (see Fig. 3). The proposal does not include a discussion about the learning contents, the different types of users, the goals of the game, or the way in which learning is measured.

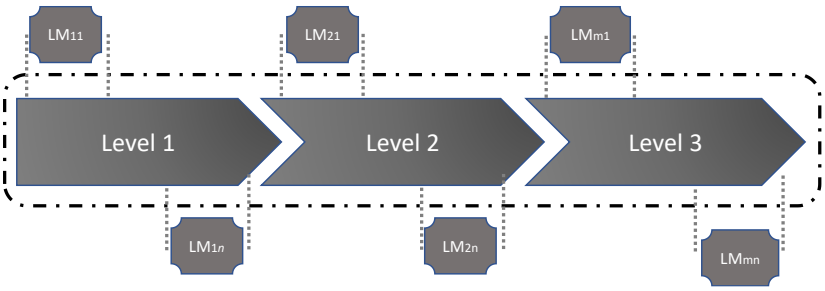

Figure 3: Barbosa Methodology Model

Cano et al. (2016) define a methodology for creating serious games for children with hearing problems. They call this methodology MECONESIS, which includes four phases (see Fig. 4). His research presents a traditional software development methodology, which uses metadata such as Instructional Management System to describe scenarios and BPMN to model processes. The analysis phase contains three very important parts, 1) defining the needs of use, 2) establishing pedagogical and recreational objectives, and 3) establishing the interests and needs of the user. While the pre-production phase is related to the design of the game interface. This part includes design patterns, software patterns for implementation, and design guides for children with hearing impairments (Cano et al., 2016).

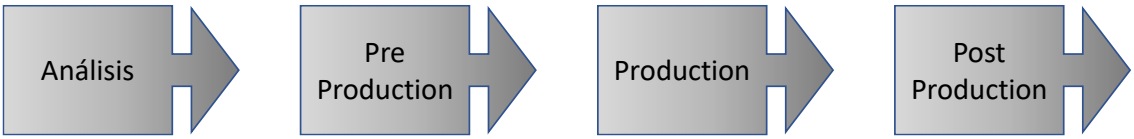

Figure 4: MECONESIS Methodology Model

De Lope (2017) presents a methodology that contains five phases: startup, design, production, test, and postproduction (see Fig 5). The design phase includes suggestions on a set of key elements such as the setting, the characters, and the educational challenge. The game structure considers scenes, actions, and dialogues. However, it is not presented how the learning contents are included in the game.

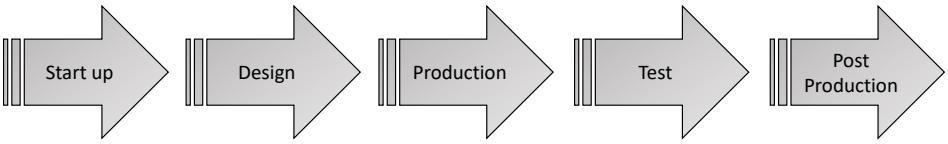

Figure 5: De Lope Methodology Model

Silva (2019) proposes a methodology that emphasizes the development stage of the project before the production of the game. He covers a significant number of steps to define the learning mechanisms in a serious educational game. Fig. 6 shows the diagrams of the steps that the author considers important. Silva explains that the steps represented by a rounded rectangle are related to learning mechanisms or learning outcomes, while the other rectangles are associated with game features. He adds that the dashed lines signify iterative loops, where the mechanics can be refined based on user experience or learning outcomes.

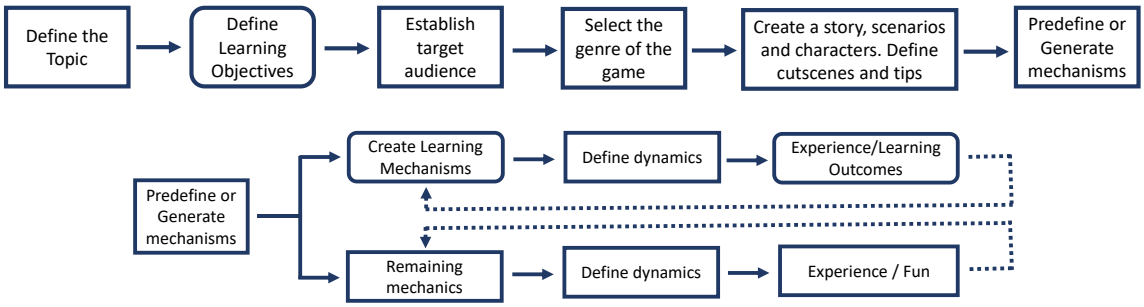

Figure 6: Silva Methodology Model

3. Proposal for a Participatory Methodology

The literature narrates the benefits of using SGs in the classroom. However, the creation of each serious game is not a simple or easy task, it is frequently that the expectations of the educational designer or the user are not satisfied. There are few methodologies that have been proposed that contemplate an integral design, or that explicitly specify the tasks that must be carried out in each stage. While it is true that the production stage (or development) belongs to the developers, and the testing phase with users regularly belongs to the academic counterpart, the design stage is the opportunity to work collaboratively. The methodology that authors propose has five phases (see Fig. 7), however the purpose of this article is to focus on the first phase (see Fig. 8).

The first phase begins with the creation of a team that integrates experts in software development, experts in pedagogy and experts in games. The authors suggest dividing this phase into different elements: a) Pedagogical elements, b) game definition, and c) interaction design and data generation. These three elements are shown in Fig. 8.

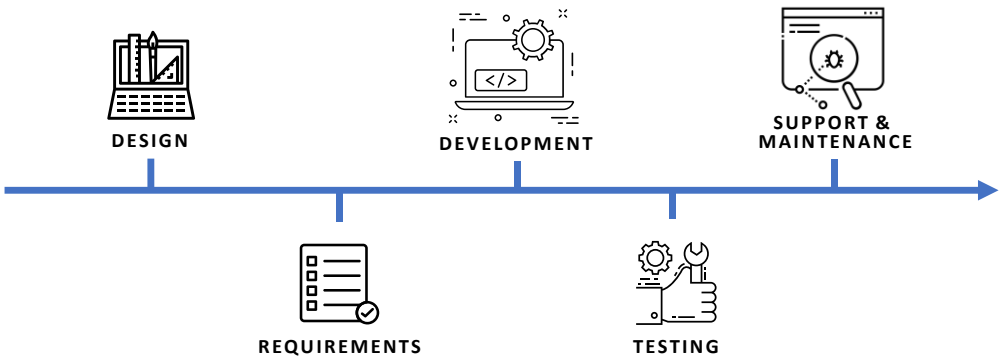

Figure 7: Proposal for a New Participatory Methodology

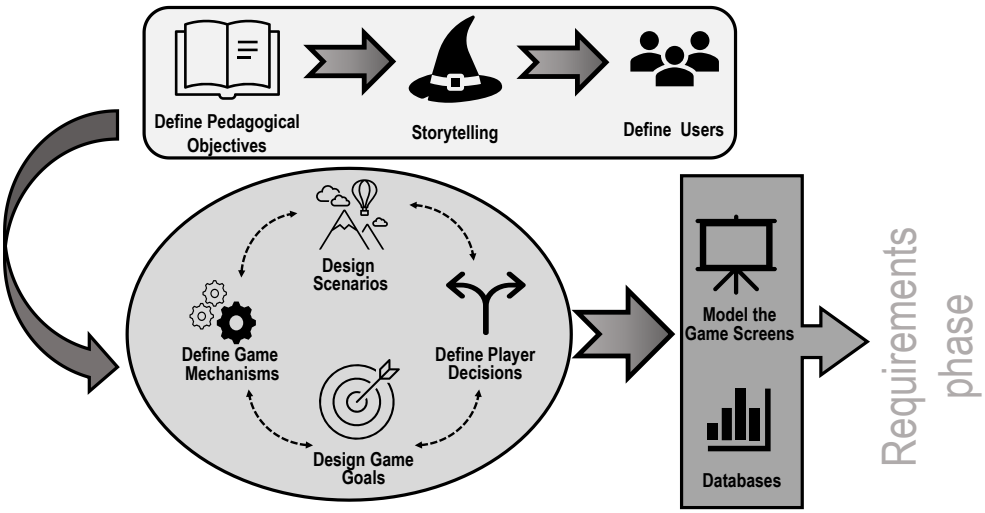

Figure 8: Proposal for the Design Phase

3.1 Pedagogical Elements

The birth of the project must come from the academic part, it should come from an idea to transmit knowledge or develop a skill in students and assume that a playful tool can help in it.

Formulation of pedagogical objectives. In this part, we recommend using Bloom's taxonomy to specify the scope that is desired when using the game. It is recommended to start with the most basic verbs in taxonomy. It is also possible that it is declared to develop some kind of competence in the students. In any case, the statement of these objectives should be the guide for the development of the game. On the other hand, this statement is known as product purpose definition. The definition helps the client and developer to have clear objectives that allow comparing the product and defining whether it meets the requirements of the client.

Creation of Storytelling. The development of the story should be a creation of the pedagogical expert along with the game expert. The story must be compelling, generate commitment from the students to find a solution, preferably. The challenges or dare of the game must be aligned with the contents of the topic under study. A congruence is expected between the decisions made by the players and the effects that are observed in the game. If the consequences are aligned or congruent with the real world, students will be able to obtain more learning. Storytelling provides context for the player and introduces relevant topics to the game.

Define Users. The definition of users is important because this must be relevant to the story. If users have little familiarity with the problem, then storytelling should be more scrupulous, explaining every detail more precisely. If, on the contrary, the users have experience in the concepts that the game handles, we must take care that the game has greater depth, and the level of difficulty should be challenging for the users.

3.2 Game Definition

This element is fundamental in this phase and teamwork of the three team members (the academic expert, the game expert, and the developer) is suggested. The definition of each factor depends on the definition of the other components. In this sense, there is an interaction between the four features involved in this step. All the elements are interconnected, and that is why it cannot be seen as a set of serial steps, but rather as an iterative process to bring the right solution from all disciplines and this supposes a continuous adjustment between each one of them.

Define Game Mechanisms. This component is one of the most important. Very often, the definition of the mechanisms also means the way in which the players will create strategies or make decisions. This is why these mechanisms must be clear to all players, each one of them must understand how they can advance in the game and what are the set of available options. The pedagogical expert must make these mechanisms congruent with the learning objectives, the game expert should take care that the mechanisms are fun and challenging, finally, the developer must be present in these discussions since this will be key for technological development. It is desirable that unexpected events occur that challenge the creativity of the player. Performing the same operation throughout the game is not very motivating for the participants.

In this step, it is important to specify if the game is individual or collaborative, asynchronous or synchronous, if the decisions of one player affect the scenarios of other participants, how many rounds should be played, etc. It is recommended to write and fully define the rules of the game.

Design scenarios. A game could represent a continuous story, or it could be divided into different parts, or scenarios, or simply, in turns. Each scenario could represent a continuation of the story, or it could be a different story with different features, facts, situations, or characters. The scenarios offer the opportunity to generate new variables, new decisions, new interactions, new challenges, or to increase the level of difficulty. This is why it is important that the academic expert is the one who develops this part together with the game's expert. Obviously, it is important that the developer is present in this discussion to understand what variables should be incorporated, and how these variables will relate to the existing ones.

Design Game Goals. The academic expert defines the goal of the game, and it is desirable that the rules are clear to all players before they start the game. The objective is to describe how to win or what the player must achieve to be successful. What the players do in the game must be related to the objectives of the game. If the players make a set of decisions, hopefully this will provide a score for the player's performance within the game. It is to be expected that the person who obtains the highest scores demonstrates greater skill or knowledge than other players. This also means that game goals and learning goals must be aligned.

Define Player Decisions. This part is focused on generating engagement and fun, but they must be aligned with the pedagogical objectives. The decisions of the players or those actions that they must carry out are focused on demonstrating the skills or knowledge acquired. Every time the player interacts with the game, it is an opportunity to demonstrate this learning. Within a well-designed game, the decisions could show the level of proficiency that the participant has acquired knowledge or developed a skill.

3.3 Screens and Databases

This is the last part of the design phase. As in most of the design, it is desirable that the three experts work collaboratively and establish agreements before moving on to the requirements phase.

Model the Game Screens. This step is important because all the elements that the players will have access to when they must perform an action must appear on them. It is possible that at that time, players need some type

of data, notification, or relevant information. In this case, it is convenient for the pedagogical expert to point it out so that the other participants can propose the way in which the information or events that should be displayed on the different screens should be established.

Define Databases. This component is important in terms of the feedback that must be provided to the participants to provide them with a better learning experience. The authors suggest that this part should be defined in terms of what are the decisions or actions that show that the participants have acquired knowledge or developed a skill. The intention of an educational game is to provide information to tutors and participants in relation to the achievements. Sometimes it will be necessary to save the player's decisions throughout the game, at other times it will be enough to save the player's final score. It is also convenient to define if the players will have access to the results of other players (so that they can compare their performance).

4. Conclusions

The interest in the development of computer games that can be used as educational tools is evident. This is due to the multiple benefits that games have reported in the literature in recent years, the type of student that is coming to the classroom, and the development of information and communication technologies.

There are some proposals on various methodologies that can be used in the creation of games. However, there is a lack of detail in the steps that should be followed at each stage. There are currently no practical guidelines for what academics, game experts, and developers should work with at the various stages.

In this article we try to detail only the stage that corresponds to the game design, trying to be specific in what should be discussed during this phase. The interest in narrating this element is that, from our experience, many projects fail or last longer than expected because this phase is not worked with the required details. The goal is to raise awareness that in the vast majority of cases, developers, academics, and game experts use a different language, so joint work is essential for the development of common ideas within the group.

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What do we Evaluate in Serious Games? A Systematic Review

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Abstract: Serious games have emerged as an invaluable tool in education, revolutionizing the way students learn and engage with complex concepts. These games combine entertainment with educational content, creating immersive and interactive experiences that enhance learning outcomes. This strategy has positioned themselves as a powerful educational tool recommended for the new generations due to their benefits in terms of motivation, engagement, active learning, development of skills, and adaptation to diverse learning styles. By integrating serious games into educational programs, educators can enhance meaningful learning, foster relevant skills, and prepare students to tackle the challenges of the 21st century. The evaluation of serious games is important for various reasons. For example, it helps determine if a serious game meets its educational objectives and truly promotes learning and the development of specific skills. It also provides feedback on the design, gameplay, effectiveness, and other aspects of the serious game, allowing developers to identify strengths and areas for improvement to optimize the learning experience. Evaluations help determine if the serious game appropriately caters to the needs and characteristics of users, if it is suitable for the target group, if it is accessible to individuals with different abilities, and if it provides an appropriate level of challenge to promote engagement and learning. Ultimately, evaluations provide validation and credibility to serious games as educational tools. This study shows a systematic review of the factors that appear most frequently evaluated, the methodology used, and discusses the possibility of adding new factors and points out the need to consider the opinion of other users to improve the evaluation of these resources.

Keywords: Educational innovation, Higher education, Serious games, Game-Based learning, Simulations

1. Introduction and Literature Review

Serious games (SG) have gained increasing attention over the years as they provide a unique way of engaging individuals in learning and training activities (Bellotti, Berta and Gloria, 2010). Learning games have been developed to provide an entertaining and engaging way for individuals to acquire knowledge and skills, while also promoting retention and transfer of learning. These games are designed to facilitate learning in a fun and interactive way, with a focus on enhancing engagement and motivation (Cheng, Huang and Hsu, 2020; Naul and Liu, 2020; Meij, Veldkamp and Leemkuil, 2020). On the other hand, there are authors who affirm that SGs help students to develop critical thinking skills (Madani, Pierce and Mirchi, 2017), improve retention (Bergeron, 2008), increase creativity (Riedel and Hauge, 2011), develop problem-solving skills and decision making (Pacheco-Velazquez, 2022).

One advantage of learning games is that they can provide a safe and controlled environment for learners to practice and apply newly acquired skills and knowledge. For example, simulations can be used to provide learners with an opportunity to practice complex tasks in a realistic setting, without the risks associated with real-world applications (Pacheco-Velazquez and Aguilar-Avalo, 2019; Deshpande and Huang, 2011). Furthermore, games can provide immediate feedback to learners, allowing them to learn from their mistakes and adjust their strategies accordingly (Bellotti et al., 2013).

Learning games can also be tailored to the individual needs and preferences of learners. Individualization, which refers to the customization of the game to the learner's abilities, preferences, and learning style, has been found to enhance engagement and motivation, leading to more effective learning outcomes (Hamari and Tuunanen, 2014; Dobrovsky, Borghoff and Hofmann, 2019). This approach can also help to address the challenges of catering to the diverse needs of learners with varying levels of knowledge and skills (Pacheco-Velazquez and Viscarra-Campos, 2019).

It is important to take individual differences between players into account when designing a SG. Different people learn at different speeds and through different learning styles. Furthermore, players may use different strategies and play styles during the game, and their range of skills and abilities may vary (Xu et al., 2019; Sottilare and Gilbert, 2011). It's also important to recognize that the player interacting with the game is dynamic, which can

lead to issues like loss of motivation or predictability. Considering the individual characteristics and the learning style of the players can affect the perception of the effectiveness of the game (Lindberg and Laine, 2018).

There are many factors that contribute to explaining the effectiveness of SG. In an investigation carried out by Calderon and Ruiz (2015) eighteen factors are listed: aesthetics and design; social impact; interface; player efficacy, motivation, behavior, attitude, emotions, satisfaction, enjoyment, commitment, acceptance, and performance; playability, learnability, and understandability; utility; and educational aspects. In addition to these factors, other studies have identified elements such as feedback, challenge, interactivity, and immersion as key components of SG effectiveness (Soflano, Connolly and Hainey, 2015; Boyle et al., 2016). Other authors have added to all these factors the importance of the setting, the integration of the game with learning, interaction, feedback, and game design (Faizan et al., 2019; Marsh, 2011).

However, there are still several unresolved issues regarding SGs. For instance, some researchers have supported the notion that there is no established methodology for measuring the effectiveness of SGs (Hersh and Leporini, 2019; Serrano-Laguna et al., 2018). Moreover, several factors are poorly defined, leading to confusion about how to measure them (Fokides et al., 2019b). Other researchers have argued that the evaluation of SGs' functional components remains unclear (Zhonggen, 2019) or that it is biased (Connolly et al., 2012). Perhaps the most significant challenge is evaluating SGs. Given the complex nature of their development involving experts from various fields, it is essential to have robust evaluation frameworks that consider all relevant factors, or at least as many as possible (Fokides et al., 2019a). However, this task is nearly impossible due to the diverse genres of SGs, covering different subjects and targeting various user groups.

A very important consideration is to understand what is meant by the effectiveness of a SG. Some authors have focused their studies on specific factors. For example, the impact of SG on engagement and motivation (Kiunsi and Ferwerda, 2019). Others evaluated the role of interface, workload, and usability (Thorpe, Nesbitt and Eidels, 2019). Or the transfer of knowledge acquired during gameplay to real-life situations, which has been highlighted by researchers (Blumberg et al., 2013). Fokides (2019b) affirm that the existing literature on SG is fragmented in terms of the SG that were studied (including their learning content and genre), the context in which they were studied (including target groups and settings), and the factors that were considered. Moreover, there is a lack of research that considers many salient factors. As a result, more research is needed to determine which features are significant in shaping SG learning effectiveness, which can help to resolve ongoing debates about the role of certain factors.

2. Methodology

This study presents a systematic review of scientific literature on SG, focusing on the evaluation factors that researchers have used to assess different SG. The review was conducted following the guidelines of the PRISMA statement for conducting systematic reviews (Moher et al., 2009; Welch et al., 2016). The following sections will detail the different phases of the review process.

2.1 Systematic Literature Review

In this work, a systematic review of the published scientific literature on SG and their evaluation has been carried out. For its preparation, the guidelines of the PRISMA declaration for the correct performance of systematic reviews have been followed (See Fig. 1). The elaboration process will be detailed in its different phases.

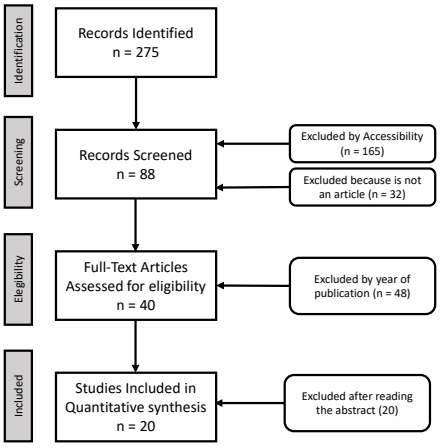

Figure 1: Prisma Flow Diagram

2.2 Screening of Documents

Phase 1. Identification: The first searches were carried out in April 2023. The search was performed on the SCOPUS databases using the following parameters: TITLE-ABS-KEY: ((scale OR survey) AND (factors AND serious AND games)). The initial search yielded 275 documents.

Phase 2. Screening: The search was then narrowed down to only include documents marked as "All Open Access" resulting in 110 documents. Further narrowing the search to only include journal articles resulted in 88 documents.

Phase 3. Eligibility: The search was limited to articles published within the last three years (2021 to present), resulting in a final set of 40 documents.

Phase 4. Included: After reading the abstract, we recorded 20 documents.

The combination of terms that yielded the best results was the following: TITLE-ABS-KEY((scale OR survey) AND (factors AND serious AND games)) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (PUBYEAR,2023) OR LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021))

A summary of the inclusion and exclusion criteria is shown in Table 1.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Open Access	Year of Publication: 2020 or before
Article in Journal	

3. Results

A summary of the results we found in the systematic review is presented in Table 2.

Table 2: Summary of results

Author and Year	Study application topic	People considered in the study	Methodology (Data Source)	Variables under study
You et al., 2023	Medicine. Health Care.	Women with cancer	Self-reported surveys and data collected from tablets.	Engagement
Brill et al., 2022	Psychiatry, Medicine, Health Care.	Patients with gambling disorder	Magnetic resonance imaging.	Emotional Control
Mittmann et al., 2022	Computer Science, Mental Health.	The study focuses on pre-adolescent children (10 to 12 years of age)	Surveys and questionnaires	Social Skill Trainings and Social and Emotional Learning
Wong et al., 2022	Nursing.	Higher education students in nursing and medicine	Scoring system with specific mechanisms	Teamwork and learning outcomes
Van Gaalen et al., 2022	Education.	Higher education students in dental and medical studies.	Selection and prioritization of factors on game preferences.	Identification of preferences for game features.
Mystakidis & Christopoulos, 2022	Education.	Teachers from STEM area.	Mixed research study involving a validated survey questionnaire instrument and an online debriefing session	Benefits of using technology in the classroom

Author and Year	Study application topic	People considered in the study	Methodology (Data Source)	Variables under study
Tanner et al., 2022	Finances, Ethics.	Higher education students in banking and finance	Using a study pre-test post-test questionnaire	Promote moral sensitivity in business. To examine the role of social pressure.
Bennis, Kandali & Bennis, 2022	Education.	PhD students	Surveys and questionnaires	Students Motivation. Generation of an adaptable learning game.
Herne et al., 2022	Information Technology, Education, Health Care.	Stroke survivors	Results and score obtained in the simulator	Engagement
Janssen et al., 2022	Health Care.	Adult patients undergoing chemotherapy	Semi-structured interviews	Breaking up the monotony of treatment.
El Machtani El Idrissi et al., 2022	Health Care.	Older adults with major neurocog-nitive disorder	System usability scale and Semi-structured interviews	Usability of the game
Swinnen et al., 2021	Mental Health. Behavorial Sciences.	High Schools Students	Qualitative data and notes. Semi-structured interviews.	Awareness, empathy, commitment.
Gijzen et al., 2021	Health Care.	General population	Questionnaires and surveys.	Behaviour changes.
Suppan et al., 2021	Enviromental.	Architecture undergraduate students	Questionnaire survey and participant observation complemented by interviews	Behaviour changes. Learning.
Gao, Guo and Jiang, 2021	Bioengeneering.	Volunteer specialists in risk management/ar chitecture/engin eering with more than 5 years of experience	Surveys and qualitative data.	Behaviour of users in a risk environment.
Cavalcanti et al., 2021	Psychology. Health Care.	Adolescents between 11 and 15 years	Surveys and questionnaires. Comparison of results between people who completed and did not complete the game.	Improved self-esteem, affect balance, emotional symptoms, behavioural problems, and hyperactivity
De La Barrera et al., 2021	System Innovation. Informatics. Artificial Intelligence. Machine Learning.	General population from different continents	Comparison of game outcomes between people who played the game the most times (engagement).	Identification of behaviour patterns. Behaviour changes. Engagement.
Hollerit et al., 2021	Technology. Applied Sciences. Neuroscience.	General population divided into two groups according to their age.	Data obtained from the near-infrared brain function imager	Games have a positive training effect on reducing cognitive function decline.
Ge et al., 2021	Education.	Students from introductory	Application of pre and post questionnaires.	Improve learning. Meaningful learning.

Author and Year	Study application topic	People considered in the study	Methodology (Data Source)	Variables under study
		Psychology courses in Higher Education		
Hummel et al., 2021	Rehabilitation. Health Care	Older adults with major neurocognitive disorder	System usability scale and semi-structured interviews	Usability of the game

4. Discussion, Conclusions and Future Works

Serious games find their primary applications in the areas of Health Care (50%) and Education (20%). In the realm of Health Care, the development of these games often incorporates technologies such as virtual reality or augmented reality. The number of research studies on SG in the healthcare field (medicine, nursing, or related areas) seems representative. The use of these games to prevent certain types of mental illness or to create attachment and loyalty to a treatment seems like a very interesting application of these resources.

The distribution of data sources in serious game research indicates that in 30% of the cases, the data is collected from users who belong to some type of school system, particularly higher education students. These students are often participants in educational interventions that utilize serious games to enhance learning experiences and develop specific skills within academic settings.

Additionally, in another 30% of the cases, the participants are patients who use the serious game. This highlights the significant role of serious games in the Health Care area, where they are employed as therapeutic tools or interventions to support patient care, rehabilitation, and health-related outcomes.

The data presented indicates that in the majority of cases (55%), data in serious game research is collected through questionnaires, surveys, or semi-structured interviews. These methods are commonly used to gather subjective feedback, attitudes, and perceptions of participants, providing valuable insights into their experiences and perceptions related to the game-based intervention.

In only 10% of the cases, a scoring system has been developed within the serious game itself, allowing for the measurement of the game's results. This scoring system is likely designed to objectively assess participants' performance, progress, or achievements within the game, providing quantifiable data on their in-game actions and outcomes.

Interestingly, in another 10% of cases, the data is measured using some form of tool that allows for the measurement of the participants' brain function. This could involve the use of neuroimaging techniques such as EEG (electroencephalography) or fMRI (functional magnetic resonance imaging) to study participants' brain activity during gameplay. This approach provides valuable neurophysiological data, enabling researchers to understand how the brain responds to serious games and the cognitive processes involved in the learning experience.

The diverse methods of data collection in serious game research reflect the multidisciplinary nature of the field and the different objectives researchers aim to achieve. While questionnaires and interviews provide insights into participants' perspectives and attitudes, scoring systems within the game enable objective performance measurement, and neuroimaging techniques offer a deeper understanding of the cognitive processes underlying the learning experience. This variety of data collection approaches enhances the overall comprehension and evaluation of serious game effectiveness and its impact on learning outcomes.

An important finding in the systematic review is that although SG is associated with educational purposes, most studies (more than 50% of them) look at changes in player behavior, motivation, or involvement. That is, most of these studies do not focus on measuring the gains associated with user learning, but rather on observing increased engagement, increased motivation, attitude changes, or behavior pattern changes.

The systematic review conducted on various studies involving the use of SG reveals a predominant focus on measuring the effectiveness of the games rather than the specific characteristics associated with them. Among the studies reviewed, only two investigations include user feedback on factors such as feedback, interactivity,

flow, challenge, attention, interest, involvement, clear instructions, among others (Herne, 2022; Van Gaalen et al., 2022).

It is also worth noting that, among these 20 articles, just one of these studies (Mystakidis & Christopoulos, 2022) considers making an evaluation of the tutors or teachers involved. It is crucial to evaluate not only the effectiveness of the SG on the end-users, but also on the educators who are using the game in their teaching. This can provide insight into how the game can be improved to better support the educators' teaching goals and help them to effectively integrate the game into their curriculum. It also highlights the need for more research to be conducted on the impact of SG on educators and their teaching practices.

Finally, the authors consider that a good practice would be to conduct more studies considering the opinions of the people who coordinate the use of these resources (teachers, tutors or coaches). Surely their experience could be useful for improving these tools. It is also suggested to create elements that allow us to measure the opinions of users in terms of fun and engagement with the SG.

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Using an Escape Room Activity to Enhance the Motivation of Undergraduate Life Science Students in Mathematics Classes: A Case Study

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Abstract: Mathematics is one of the school subjects where demotivation, dislike and failure are frequent concerns. To address this, it is important to actively engage students in the classroom and employ resources that make math classes more appealing and captivating, leading to meaningful learning experiences. Active, cooperative, and participative learning methods should be prioritized over traditional didactic teaching and the mere transmission of knowledge. Active learning methods offer alternative approaches to the conventional lecture format, actively involving students in the learning process. The concept of an escape room, a gaming experience where participants must solve challenges to escape from a locked room, has gained popularity in educational contexts. The educational escape room is an extension of this concept, aiming to promote real-time problem-solving, teamwork, and discovery of clues and mysteries to facilitate active learning. By engaging in various tasks within a room, students work together in teams, fostering an active learning environment. The educational escape room offers several benefits, including the enhancement of problem-solving skills, student performance, and motivation. By incorporating gamification strategies into teaching and learning processes, this approach proves to be an effective way of promoting active learning in mathematics. In this paper, we present a case study that explores the use of an educational escape room with first-year undergraduate students from a Portuguese higher education institution, with the goal of improving their mathematical problem-solving skills. The study aims to evaluate how escape rooms can contribute to increased student motivation. To assess the perception of students regarding this escape room methodology, a quantitative survey was conducted. The findings indicate that using the escape room as an educational approach effectively increased student interest and improved learning outcomes in mathematics.

Keywords: Higher education, Educational escape rooms, Mathematics education, Game-Based learning, Active learning, Problem solving, Soft skills

1. Introduction

Mathematics, considered one of the basic areas of various education settings, is one of the school subjects where demotivation, dislike and failure are frequent concerns (Faulkner et all, 2014, Maharjan et al., 2022). Mathematics is often perceived as a challenging subject by many students, characterized by the need for memorization and repetitive tasks, lacking in interest or practical application. This outcome can be attributed to the traditional approach to teaching (Dhakal, 2018; Dahal et al., 2019), which emphasizes the transmission of knowledge and places value on memorizing procedures and content through repetitive exercises.

Engaging students in the classroom and utilizing resources that make math classes attractive and captivating is essential in fostering meaningful learning experiences. The undeniable importance of mathematics in everyday life and individual development further emphasizes the need for such engagement. One of the key challenges in mathematics education lies in addressing the lack of motivation among students towards the subject. According to several authors (Matos, 2011; Entwistle and Ramsden, 2015; Pais et al, 2018; Hall and Pais, 2018; Maharjan et al., 2022), motivation plays a crucial role in any learning process as it impacts not only the ability to acquire knowledge but also the quality of learning itself. The level of motivation we possess significantly influences our engagement and success in the learning process.

The world we live in is continuously evolving and undergoing constant change. The educational context is no exception and requires a renewal of paradigms (Morin, 1999; Voštinár and Mandrichenko, 2022). Often, teachers are faced with discouraged students: with glassy eyes, heads down on desks, students who do not remember content taught to them the day before! Mathematics classes are no exception. Quite the opposite! Profound changes to the role and function of both teachers and students are particularly vital. It is necessary to go beyond the traditional; the teacher must look for resources that make classes flow, so that the students acquire or increase their interest in mathematics. The Joint Mathematical Council of the United Kingdom (2011) states that it is of the utmost importance that the teaching and learning process of mathematics becomes more stimulating, taking into account modern society and the students' interests. Active, cooperative, and

participative learning methodologies should be prioritized over traditional didactic teaching methods that focus solely on the transmission of knowledge. One of the greatest challenges faced by teachers today is to effectively engage students, motivate them to learn, and encourage them to actively participate in their own learning process (Katsaris and Vidakis, 2021). If students develop motivation to learn a subject, they are much more likely to develop long-term understanding (Lester, 2013, Maharjan et al., 2022).

Active learning occurs through playful activities creating powerful learning environments (NCTM, 2020). Integrating games as a playful tool offers learners the opportunity to engage in imaginative scenarios and challenges, which can also be collaborative in nature and governed by specific rules. This approach allows for a quantifiable outcome, adding a measurable element to the learning experience. (Vidakis et al, 2019; NCTM; 2020, Vidakis et al. 2020; Papadakis, 2020; Kalogiannakis et al., 2021).

In the last decade, the interest in fostering motivation with gameful approaches has been rising (Koivisto and Hamari, 2019).

As lecturers in higher education within the polytechnic sector, the authors are faced with all these changes and cannot help but reflect on them and consider what their contribution (however small it may be) could be to improve the quality of higher education in Portugal.

One of the authors being a mathematics teacher, she is also confronted year after year with the demotivation, lack of interest, and subsequent failure of students in relation to mathematics subjects.

These reasons formed the starting point for the project "You can escape from the room, but not from Knowledge." Given the imperative need for changes in the educational model, a different perspective on learning and the role of teaching and learning methodologies is essential. It is crucial to prioritize active, cooperative, and participative learning methodologies, breaking away from traditional lecturing and mere "knowledge transmission." In order to reverse the existing and widespread sentiment towards mathematics, it is necessary to motivate and foster interest, thus promoting student success in mathematics subjects.

Guided by the research question, "How can we motivate and foster interest in mathematics, making the learning process more engaging?" the authors developed an escape room activity in the field of mathematics for first-year students in a life science course.

2. Escape Rooms and Learning

Escape Rooms

Escape Rooms (ERs) are “live-action team-based games where players accomplish tasks while participating in multiple procedures, in one or more spaces, with a specific goal, in a limited period of time” (Nicholson, 2015). ERs appeared initially in Japan in 2007, but have grown in popularity worldwide, with rooms available across most continents including Asia, Europe and America (Makri, Vlachopoulos, & Martina, 2021). ERs provide players with an immersive narrative experience, creating a meaningful and memorable escape scenario. Players are transported into a narrative circle where they are faced with intriguing challenges and missions. Whether it's capturing a group of thieves who have stolen valuable artwork from a museum, retrieving important notes from a locked school locker before an upcoming exam, or saving the planet from a nuclear threat, these narrative-driven scenarios evoke emotional investment and curiosity among players. As they navigate through the rooms and solve the presented challenges, the game atmosphere is set, fostering engagement and a sense of adventure.

Educational Escape Rooms

Escape Rooms have become a popular recreational activity which has also drawn the attention of teachers and educators in recent years. Educators are increasingly motivated to incorporate Escape Room games into diverse educational contexts. Educators are increasingly inspired to adapt Escape Room games into various areas of education (Cable, 2017; Clarke et al., 2017; Nicholson, 2018) as a method to develop playful and productive failure techniques for encouraging continuous development (Whitton, 2018). Educational Escape Rooms have been shown to be a fun and entertaining activity if brought to the classroom. At the same time they have been proven to be a solid activity where, while trying to break out of the room, students can develop soft skills as well as subject-matter related competencies (Morrell et al. 2020, Sowell 2020). A systematic review carried out by Fotaris and Mastoras (2019) highlights their positive impact on student motivation and soft skills development such as teamwork, creativity, decision-making, leadership, communication, and critical thinking, and emphasises the enjoyable experience that immerses students as active participants in the learning environment.

"The Escape Rooms methodology provides a playful foundation for learning experiences to be designed into a more contextualised manner. Using narratives […] could invoke the much-needed curiosity and motivation to be persistent on problem solving" (Arnab et al. 2021, p.2).

3. Methodology

Research Aim, Procedure and Instruments

The aim of the study is to evaluate how Escape Rooms can contribute to increase students' motivation, making the learning process more interesting and promoting a more positive attitude towards mathematics. The authors chose to conduct a case study, with primarily exploratory intentions. To facilitate this experience, inquiry techniques and direct non-participant observation were employed, and the data collection instruments included a final questionnaire and field notes. In this article, we present an analysis of the questionnaire responses and the researchers' observations obtained through direct non-participant observation.

In non-participant observation, the researcher assumes the role of an external observer, not taking any initiative in the evolution of the situations he/she observes (Marietto, 2014). The non-participant observation method was utilized by the authors to capture and document non-verbal cues and insights during the game situation. This approach involved observing the participants in the Escape Room without any interference from the researcher, thus enabling the documentation of challenges, dynamics, and spontaneous behaviors and attitudes. By employing non-participant observation, the authors aimed to evaluate the effectiveness and impact of the Escape Room experience.

To understand how the methodology of this Escape Room was perceived by the students, quantitative and qualitative data were collected through a questionnaire developed by the researchers. A preliminary version of this instrument was analyzed by three higher education teachers, tested with four individuals from the same group, and modified based on the suggestions collected and difficulties detected during its completion. Statistical analyses were performed with Excel and Statistical Package for the Social Sciences (SPSS), version 28. Descriptive statistics (frequencies, mean and standard deviation) were computed to examine the results.

Participants

The case study was conducted at a higher education institution in the central region of Portugal. The participants were undergraduate students majoring in Life Science, specifically enrolled in the Mathematical Analysis II course during the second semester of the academic year 2021-2022. The case study included a total of 20 students, with 19 of them completing the questionnaire. Among the respondents, 16 (84.21%) were female, and 3 (15.79%) were male. The age of the participants ranged from 18 to 24 years. It is important to note that this was a convenience sample, meaning that the participants were easily accessible to the researchers.

Study description

The Escape Room was designed by two researchers of this study, a mathematics teacher and an ICT teacher, who created the challenges that the students had to develop in order to escape the room. Prior to carrying out the activity, the Escape Room was tested at the school by a group of 3 students and 2 teachers aged 18-41 years.

The two teachers in charge of the Escape Room acted as observers, refraining from interfering with the game. The participants were divided into four groups, each consisting of five students. They were placed in a university classroom for a duration of 30 minutes. An introductory video provided information about the game's objective and the time limit. The students were then prompted to begin solving the challenges, with a stopwatch keeping track of the time remaining for them to escape the room.

The first clue presented the students with a mathematical problem that needed to be solved in order to obtain the code for a safe. Inside the safe, the key awaited, which would allow them to successfully escape. The students received assistance in tackling the mathematical problem through various challenges that provided helpful hints and guidance.

In these challenges an invisible ink pen was used to write the hints on paper, which could only be read by using a fluorescent light, a stack of books that hid the hint on a particular page, only revealed by solving a mathematical operation, and a magnifying glass to read a formula, which could only be read by using it. In order to overcome the challenges, the students had to carefully follow the provided clues, which guided them towards understanding the ultimate goal and the steps required to obtain the necessary hint. Armed with these clues, the students would return to the initial mathematical problem and attempt to solve it. The solution to this problem yielded the code for the safe, which contained the key to escape from the room. Upon successfully

using the key to exit the room, the students' completion time was recorded. This facilitated the identification of the winning team based on two criteria: successfully solving the challenge and doing so in the shortest amount of time.

4. Findings

This paper intends to evaluate how an escape room activity can contribute to increase students' motivation and if it contributes to improved learning outcomes.

To reach this goal, direct observation, field notes and analysis of a quantitative survey were the main instruments used.

Regarding the objective stated previously – investigate if an Escape Room activity contributes to increase students' motivation – several results may be reported.

Field notes analysis

The teachers observed that the participants in the activity thoroughly enjoyed and found the Escape Room (ER) experience to be highly enjoyable and entertaining. According to the students' feedback, this type of active and dynamic class proved to be more appealing compared to a traditional approach focused on solving exercises. Mathematics, in particular, was perceived as a more engaging and positive subject through the implementation of the ER activity. Some participants expressed their enthusiasm, stating that the classes became much more enjoyable and interesting with this interactive approach. Additionally, another group expressed a desire to see such activities extended to other topics within the curriculum and across different subjects. One student commented the following to one of the teachers: "I think the escape room was a very dynamic and fun activity to unite us as a group and challenge our math skills". These facts support a positive answer to the established objectives: evaluate if an ER activity contributes to making the learning process more interesting and promoting a more positive attitude towards mathematics.

Questionnaire analysis

To collect information about students' insights on the use of the Escape Room a questionnaire was delivered at the end of the activity. From the 20 students who took part in the activity, 19 answered the questionnaire.

The first section of the questionnaire concerned the characterization of the respondents with respect to gender and age. Ages ranged from 18 to 24 years and most students were female (84.21%), whereas 15.79% were male.

In the second section of the questionnaire, students were asked to provide their opinions on the ER activity. Using a five-point Likert scale ranging from 1 (very poor) to 5 (very good), students were asked to rate their overall evaluation of the ER activity. The results indicated that the majority of students responded positively. Only two students (10.53%) gave a neutral rating of 3, while none of the participants gave a negative response.

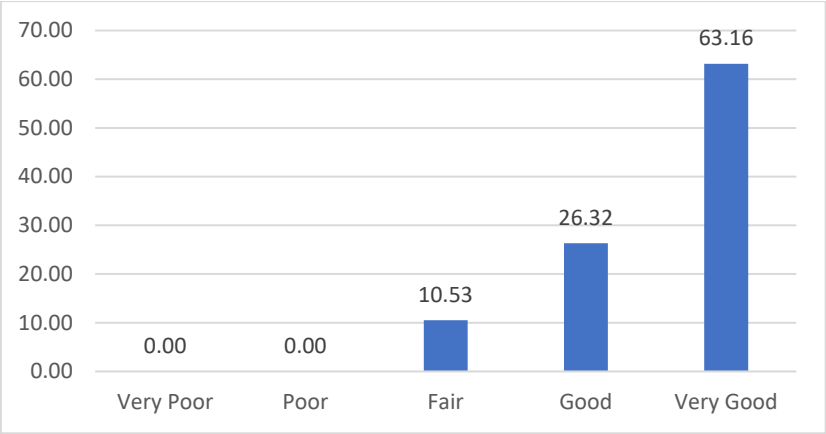

Figure 1: Rate your general evaluation of the ER activity

Analyzing the results of the questionnaire presented in Table 1, we observe that the mean values are clearly positive for most questions. The students' proficiency in digital skills was evident in their high level of ease in handling technology. The questionnaire results revealed that the ER activity served as a motivating factor for students and facilitated content consolidation, while also being enjoyable. The majority of students agreed that the activity was well-organized, the allocated time was appropriate, and the level of difficulty was manageable.

The least consensual statement, but still positive, is about the fact that they contributed to having a better grade in the CU (mean=3.21 out of 5; sd=1.07) and the fact that they learned more with the ER activity than with a class to consolidate the syllabus (mean=3.16 out of 5; sd=1.22).

Based on the information provided, it is evident that the majority of students had a positive reception to the ER activity, perceiving it as a valuable contribution to the learning process and enhancing motivation for learning. Consequently, students recommend the utilization of escape rooms as an effective teaching methodology.

Table 1: Summary of the satisfaction survey responses (answers on a Likert scale: 1-strongly disagreement, 5-strongly agreement)

	1	2	3	4	5	NOp	Mean	S. D.
1 - In general, I like to play games (video games, board games, etc)	0	0	1	7	11	0	4.53	0.61
2 – The ER allowed me to consolidate the syllabus	0	0	4	10	4	1	3.79	0.70
3 – Resorting to the ER will contribute to a better grade.	0	2	8	2	5	2	3.21	1.07
4 - I found the Escape Room to be an enjoyable experience.	0	0	0	3	15	1	4.58	0.45
5 - The ER was too difficult	6	11	2	0	0	0	1.79	0.63
6 - The ER was well organised	0	0	1	5	12	1	4.37	0.64
7 – The time allocated to the activity was adequate.	0	0	0	7	11	1	4.37	0.54
8 - I liked the ER better than the exercise-solving class.	0	0	3	4	11	1	4.21	0.80
9 - I learned more with the ER than I would have with a class to consolidate the syllabus.	1	3	3	6	4	2	3.16	1.22
10 - I recommend the ER as a pedagogical methodology	0	0	0	7	11	1	4.37	0.54

The third and last section of the questionnaire concerned the use of an ER activity in math classes. Students were asked to give their opinion, in a five-point Likert scale, about five statements.

When asked if the use of an ER activity in math classes:

- contributes to a more positive attitude towards mathematics: 18 (94.74%) had a positive opinion, 1 (≈5.26%) had a neutral opinion and no one had a negative opinion.
- makes mathematics more boring and demotivating: everyone (100%) had a negative opinion.
- makes the learning process more interactive: everyone (100%) had a positive opinion.
- it is only a way to keep us entertained for a while: 13 (68.42%) disagreed with this statement, 5 (26.32%) had a neutral opinion and 1 (5.26%) had a negative opinion.
- provides a less rigid method of learning, making it more challenging, interesting, and stimulating: everyone (100%) agreed with this statement.

Figure 2 shows the detailed responses to these questions in a heatmap with the observed frequencies. It is clear from the heatmap, and the information described above that the majority of the students find that the use of an ER activity in math classes contributes positively to the learning process (making it more interesting, interactive, challenging and stimulating) and to improve the motivation for learning mathematics.

Statement: The use of an ER activity in math classes…	**1**	**2**	**3**	**4**	**5**
contributes to a more positive attitude towards mathematics	0	0	1	7	11
makes mathematics more boring and demotivating	11	8	0	0	0

Statement: The use of an ER activity in math classes…	1	2	3	4	5
makes the learning process more interactive	0	0	0	6	13
it is only a way to keep us entertained for a while	3	10	5	1	0
provides a less rigid method of learning, making it more challenging, interesting and stimulating	0	0	0	8	11

Figure 2: Heatmap with frequencies of responses to questions about the use of an ER activity in the classroom

5. Final Remarks

The main limitation of this study is its small sample size. However, despite this limitation, the study's results demonstrate that incorporating an Escape Room (ER) activity enhances student engagement and motivation for learning by making the learning process enjoyable. These findings align with similar studies conducted by Babazadeh and Frigerio (2021), Huang et al. (2020), Nicholson (2018), and Papadakis and Stavrakis (2020). Furthermore, students perceive the ER activity as an effective tool for promoting learning and recommend it as a pedagogical methodology.

Based on the results of this study, we conclude that the use of an ER activity in math classes promotes a positive attitude towards mathematics and thus fosters motivation to learn it. Therefore, we recommend the use of ER activities in classes. It is a means to help students improve their abilities, their motivation for learning and, consequently, their performance. Overall, it contributes to a successful learning process.

This study can be valuable not only for all teachers but specifically for mathematics teachers, as it provides insights into educational Escape Rooms (ERs). The findings can serve as a foundation for educators who aim to create a fun and engaging learning environment in their classrooms while ensuring that meaningful learning is taking place.

For future research, it is recommended to include a larger sample size to further validate the results and enhance the generalizability of the findings. Additionally, investigating other aspects related to ERs, such as their impact on specific learning outcomes, different subjects or different student populations, would be beneficial for expanding our understanding of their effectiveness in education.

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Requirements and Learning Modules for Implementing a Hologram Table in University Lectures

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Abstract: Holograms are relatively new technologies that can be used in university lectures. They enhance the learning experience by adding highly detailed three-dimensional (3D) visualization of objects and environments, which leads to more engagement of students and teachers. Particularly in mining engineering education, holograms have great potential to achieve learning goals, where students often struggle with understanding complex 3D concepts. When implementing new technologies in lectures, there is a must to consider the perception of students and teachers, as well as the didactical and technical requirements of courses. The consideration of these aspects ensures an effective learning environment. This paper presents the concept of three holo-modules with gamification features designed with the main goal of supporting the learning and understanding of mining engineering content. The different conceptual modules have been developed based on different learning objectives extracted from teaching requirements and technical aspects of the lectures. The results show a requirements analysis performed and the prototypes designed to integrate a hologram table in different teaching setups, such as seminars, group work, and frontal lectures.

Key words: Requirements analysis, Hologram table, Three-Dimensional displays, Education.

1. Introduction

In educational contexts, holograms have great potential to support the achievement of learning goals of courses and the students' comprehension of content. In comparison to traditional courses, the use of holographic technologies leads to less frontal teaching and more student-centered lectures. Thus, students can create content independently, exchange ideas and possibly apply the theoretical knowledge from courses' learnings in a real-world setting (Kalkofen et al, 2020). The Partnership for 21st Century Skills identified the new skills of creativity, innovation, problem-solving, communication, and collaboration as "separating students who are prepared for increasingly complex life and work environments in today's world and those who are not" (Partnership for 21st Century Learning, 2019b). The use of holograms can encourage the development of such skills as well as the creation of an engaging learning environment, which leads to more collaboration between students and higher learning motivation (Sattar et al, 2019; Stepan et al, 2017).

The case of a hologram table is an innovation in university lectures and is still not widespread. The hologram technology displays highly detailed three-dimensional (3D) objects, structures, and environments from the table center to approximately 0.7 meters of height in a hemispherical volume (Bolognesi et al, 2022). By using lightweight goggles and control wands, users visualize and interact with the holograms, while seeing each other. In contrast, other Mixed-Reality (MR) technologies, such as Augmented Reality (AR) and Virtual Reality (VR), may have limited communication between users due to head-mounted displays that constrain potential interactions (Daling et al, 2020; Kalkofen et al, 2020). In addition, AR and VR can also create motion sickness for users (Allcoat et al, 2021). Therefore, a hologram table can overcome these limitations as they enrich learning experiences, do not restrict the field of view nor inflict motion sickness.

When implementing MR technologies in university lectures, such as a hologram table, it is necessary to consider the perception of students and teachers, as well as the didactical and technical requirements of courses. The consideration of these aspects will potentially avoid misunderstandings and can ensure the application of the technology in a useful way for the educational setup (Lowdermilk, 2013). Therefore, this paper presents the results of a requirements analysis performed as a first step in the introduction of a hologram table to support mining engineering education. Particularly in this field of studies, students often struggle to envision complex 3D concepts and field visits are mandatory in the curriculum but demanding to organize and manage. The hologram table can contribute to this context by supporting the visualization of different aspects of fields and mines in detail, promoting interaction between students and with the holograms, and allowing the creation of gamified lectures to support the learning process of students.

The insights collected were transferred into three conceptual learning modules with gamification features that support the learning and understanding of mining engineering content. In the following sections, it will be presented scientific work, the methods applied in the requirements analysis and results obtained, and the concept of three hologram modules designed. The possible applications of the hologram table and the holo-modules in lectures, benefits, and challenges will also be discussed.

2. Related Work

Holographic technologies have been already explored in different educational contexts. Barkhaya and Abd Halim (2016) identified the use in the fields of medicine, business training, engineering, pharmacology, astronautical engineering, archaeology, and early childhood education. In medicine, literature shows that holograms have been adopted for medical training (Sadeghi et al., 2022), procedure planning (Brun et al, 2019), to teach anatomical structures (Ramesh et al, 2022), and medical terminologies in English as a foreign language (Ja'ashan et al, 2022). In the field of control applications, Matišák et al. (2020, 2022) developed an online application that uses holograms to illustrate abstract mathematical models of control theory as physical meaning. The authors highlight the benefits that students can design their controllers and test them with the hologram before going on real controlling plants. Quin et al (2021) described a prototype that applies holograms in online classes at TU Delft in the Netherlands. The study focused on technical aspects and intended to improve video conferences through holo-presence and face-to-face interactions between students and teachers. More recently, Chatar et al (2023) presented applications of holograms in data visualization of drills in real space and for mixed-reality tours in well sites. The authors also highlighted the possibilities to improve users' interactions by collaborating in remote teams and voice communication between users.

Considering the use of holograms in different levels of education, it was found on Rehman et al (2021) that students and teachers from secondary education in science in Pakistan had a positive perception of holograms as a tool to increase students' interest, their long-term memory of contents and engagement in lectures. However, they also highlighted as barriers to implementing the technology the internet speed, the costs, and the lack of technical expertise from teachers. Leonard and Fitzgerald (2018) analysed the usage of MR technologies and, mainly, Microsoft HoloLens© within a secondary school in Australia. The authors identified critical points for the implementation, such as training and support for teachers and the importance of applying the technology with a focus on learning goals. They also argued that teachers and students did not engage with the hologram technology at first contact and therefore did not explore all its functionalities due to the lack of experience with these new technologies. On a gamified setup, Liesatyadharma et al (2023) used a hologram pyramid to teach analytical chemistry to students of senior high school in Indonesia. They evaluated students' performance in chemistry exercises by pre and post-tests and the satisfaction of experts with the learning game. The results showed improvement in the students' correct answers in the test and experts in chemistry approved the game as a learning tool.

The literature presented some areas of study, technologies, and educational contexts where holograms have been used to support innovative teaching. Based on this research, it was identified opportunities to further explore research in hologram tables for university lectures purpose and how it can support mining engineering curriculum.

3. Methodology

This section presents the methods used for the requirements analysis based on design thinking workshops and the Daling Decision Making Matrix (Daling et al, 2021). The analysis was developed based on qualitative research, where important factors were collected from focus groups of students and teachers to implement the hologram table in mining engineering lectures.

3.1 Focus Group Workshops

For the collection of the users' requirements, Design Thinking (DT) methods were applied as a recognized and innovative approach in requirements engineering to solve problems in a structured, agile, team-focused, and interdisciplinary way (Hehn and Uebernickel, 2018). DT is also a collaborative and iterative approach to look at complex problems from a user-centric perspective. The method is usually used for the development of products considering the needs of users, rapid prototyping, and learning cycles (Pereira et al, 2021). It consists of five phases Empathizing, Definition, Ideation, Prototyping, and Testing (Freudenthaler-Mayerhofer and Wagner, 2022), further described below:

- *Empathizing* is the first stage in human-centered design solutions. It is part of understanding the big picture of a problem by getting to know the user deeper, to understand values, experiences, and needs.
- In the *Definition* step, the problem statement is determined as well as the users' point-of-view on what challenge is most important to focus on.
- The goal of *Ideation* is to use creativity and generate as many solutions as possible for the defined challenge. From this phase, innovative ideas are created, they are combined, different perspectives are addressed and synergy within the group is created.
- In *Prototyping* users quickly develop the selected solution in a way that it can be tested and receive feedback for further improvement. In this final phase, the prototype is *tested* within the group to refine the solution on user interaction, problem understating, and getting to know the user.

Therefore, two DT workshops were performed with students and teachers from mining engineering courses. The first workshop session was held in October of 2022 with eight participants, four teachers (two from mining engineering) and four students from mining engineering bachelor's and master's programs. The first workshop focused on the Empathize and Definition phases. Students and teachers reflected on the current situation of lectures of one semester and identified potential for using the hologram table to improve the courses and tackle the challenges. In the Empathize phase, the participants defined Personas, which means fictional profiles that represent types of users of a product, having their own characteristics, goals, and needs according to different points of view (Siricharoen, 2021). After it, in the Definition step, they defined the main problem of the Persona, bringing clarity and focus for a final problem to be solved. Then, the participants described their Learning Journey by highlighting the main points of difficulty and achievements during one university semester.

The second workshop happened in December of 2022 with eleven participants including teachers, students, and the representative board of students from mining engineering. This constellation was developed to ensure that students are represented in the final solutions and that the opinion of all the users is considered in the final setups for the teaching concepts with the hologram table. In this session, the Ideation and Prototyping phases were performed. In the Ideation phase, the participants discussed ideas that would improve their current lecture contexts and created together prototypes for teaching concepts, based on the feasible ideas selected. The prototypes resultant of this phase were used as a basis for the conceptual hologram modules developed, which are in development and will still be tested in the future on the hologram table with all the users.

3.2 Daling Decision Making Matrix

In the next step, the Daling Decision Making matrix was applied to gather technical requirements related to the courses and teachers' experiences with MR technologies that could be addressed in the teaching concept with the hologram table. This matrix was developed for supporting teachers' decisions in the design and development of MR technologies in university courses. It differentiates between methodological aspects of teaching, infrastructural factors, individual prerequisites, and the teachers' knowledge, all of which influence the selection of the best MR technology (Daling et al, 2021). The matrix is shown in Figure 1.

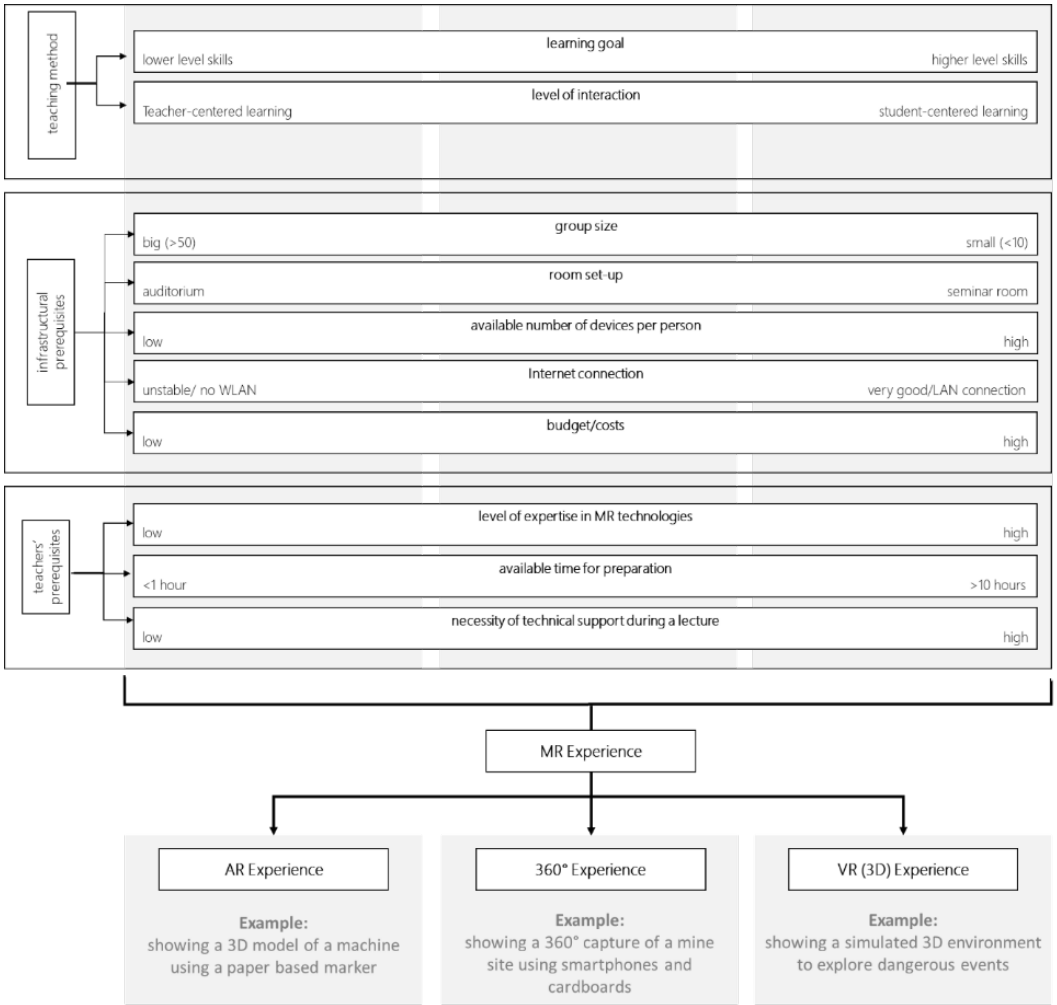

Figure 1: Daling Decision Making Matrix for Mixed Reality based courses (Daling et al, 2021).

Therefore, two teachers with previous knowledge of MR technologies filled up the matrix for selected six mining engineering courses of bachelor's and master's programs, presented in Table 1. In addition, they described in detail the courses' contents, learning goals, existent 3D models on mining structures, and options for creating new 3D data. The information collected provided input to assess technical opportunities and possible limitations in the teaching concepts with the table.

Table 1: Mining engineering lectures selected for the requirements' analysis.

Courses categories	Mining Engineering lectures
Open pit mine	Mining and Energy
	Applied Surface mining
Mine	Applied Underground Mining
	Mine Design and Simulation
Stockpiles	Reserve Modelling and Estimation
	Primary raw material economics and mineral resources

4. Results

4.1 Didactical Requirements

The requirements analysis was performed with the goal of collecting aspects that should be considered in the hologram modules concept and in the overall integration of the hologram table in the mining engineering lectures.

The students' requirements collected from the DT workshops were mainly classified into three categories: teaching methods, social interaction, and evaluation methods of courses. These were perceived as the needs and wishes of students who had already some contact with MR technologies and would like to improve learning and experiences in the courses. Regarding the teaching methods, the students wished for the use of new, innovative, and diverse methods to visualize and understand the contents. They would prefer practical activities and training, such as excursions, problem-detection games, or the planning of a mining site. In addition, they would like to use different types of media during the lectures, for example, online quizzes, MR technologies, and online exercises. In relation to social interactions, the students called for greater use of collaborative projects and more student-student interaction, where they are able to develop projects independently and use their creativity. For the evaluation methods, they reported a preference for mid-term activities or projects during the semester that could support their final exams and grades.

For teachers, the requirements gathered were categorized into modern media and social interaction. For the first category, the use of modern media**,** such as the hologram table, during lectures could help with the visualization of processes, and mining sites and with teaching structural models. On the other hand, it should be ensured for teachers that they would have the necessary technical support for the use of new technologies. In the second respective category, it is important for teachers the improvement in social interactions between the students themselves and the relationship between students-teachers. More collaboration, participation, and discussion are important points to be changed in lectures. They also wished for enabling experience-based learning for all students while improving collaborations.

4.2 Technical and Structural Requirements

The matrix developed by Daling et al (2021) was used to identify important aspects of the learning goals and the infrastructure of the courses, as well as teachers' requirements on MR media. All the lectures are intended for high-level skills as learning goals. It means that students should be able to understand and reproduce the content taught, which can be supported by the hologram table. Five of the courses lean towards teacher-centered learning, while the lecture reserve modeling and estimation is the only one based on a student-centered learning approach.

Regarding the structural prerequisites, the lectures vary in group size. While the Applied surface mining and Applied underground mining courses have a small group size, the Reserve Modelling and Estimation and Mine Design and Simulation have a medium to small group size. The Mining and Energy course has a medium group size and the Primary raw material economics and mineral resources course has a large group size. Accordingly, five of the courses take place in seminar rooms and the Primary raw material economics and mineral resources takes place in an auditorium. For the six lectures, there is a high number of MR devices available and the internet or LAN connection is considered as very good.

Regarding the teachers' technical experience with MR technologies, in four lectures there is a high level of expertise (Reserve Modelling and Estimation, Applied surface mining, Mining and Energy, Mine Design and Simulation), while for two (Primary raw material economics and mineral resources, and Applied underground mining) there is a medium level of expertise. For all lectures, there is relatively little time available for preparation and the necessity of technical support during a lecture is low to medium-low.

In summary, from the matrix results, the hologram modules applications need to maintain high learning goals for the lectures. It is also a requirement that the teaching concepts for the hologram table should be adapted to lectures in groups from small (less than 10 students), medium (around 25 students), and large groups (higher than 50 students), depending on the courses, as well as the different room types. In addition, while the table itself promotes a more student-centered experience, there is a need to have applications that encourage students to participate in teacher-centered courses. In all courses, teachers have relatively little to medium time available for preparation, and depending on the lecture, teachers might need technical support to use the modules.

4.3 Conceptual Hologram Modules for Teaching in Mining Engineering

Based on the described requirements, three conceptual hologram modules were created to introduce different practical experiences in lectures and to improve the current interaction between students and teachers. In addition, hybrid teaching, students self-learning in small groups, and frontal lectures were characteristics defined by the teachers as necessary for the teaching concepts. The hologram modules will be further technically developed and tested with users in lectures as the next step.

- 3D Whiteboard

The 3D whiteboard is an extension of traditional teaching methods with interactive features between teachers and students. The goal of this module is to enable the visualization and presentation of complex models or abstract figures in 3D space that usually students from mining engineering have difficulties understanding in 2D images. It also aims to improve interactions face-to-face and in online lectures. Teachers can upload static or dynamic 3D models to the hologram table and manipulate them on the table or via desktop. Some features of this module are the possibility of asking questions and sending answers between students and teachers on a chat, and the creation of comments, videos, or images that appear on the table display for users. Students can also visualize the contents that are presented on the hologram table, on their devices, such as smartphones, which creates more flexibility for different group sizes. On a gamified scenario, teachers can, for example, create questions on specific locations to place renewable energy systems in mining sites and reward students that answer correctly and in a determined time. Students are also able to interact with the 3D objects and can place objects on the table themselves, though the teacher can lock this function. This allows the teacher to create a competitive atmosphere between students by allowing them to place components or objects of mines planning in the most accurate position.

- Building game

The building game is a learning module that promotes group work through project development, collaboration between students, and free learning. The teachers should create different scenarios, define specific tasks for the students and evaluate their intermediate progress and results during one university semester. Students can place, move, remove, or connect items, buildings, or equipment and make decisions on their choices. Points can be attributed according to the decisions made and the explanations. This module would be used to accompany projects from lectures and provide students the opportunity to apply theoretical knowledge or to self-learn new concepts through experimentation. It is perceived that students could, for example, evaluate the pros and cons of different decisions and create new mining setups based on a realistic context.

- Game as a reward

The concept for this module is to connect the knowledge gained from other learning platforms such as quizzes, online tests, or exercise classes with the hologram table and to reward students for their participation. Depending on their involvement, students would receive prizes on the hologram table such as 3D materials or resources, which could be used to explore a mining site together as a group. The points that would be gained from the performance in the other learning platforms would be used as a budget for buying the materials, possibly bringing more motivation to students. It is also intended to enhance connections between students, to promote team spirit and collaboration. This module is also planned to be used as a chance to improve students' final grades in courses.

5. Discussion

In this study, three conceptual hologram modules were developed to support current teaching in mining engineering university lectures. Based on a requirements analysis, students' and teachers' perspectives and the technical parameters of courses were collected and translated into the hologram modules. It was observed that the hologram table is a great innovation with many functionalities that can improve teaching methods, interactions, and possibility learning results. Similar to other MR technologies, it would provide a new way to present complex 3D objects and realistic environments with more flexibility, enhancing students' engagement and learning motivation (Sattar et al, 2019; Stepan et al, 2017).

On one hand, in agreement with the literature (Leonard and Fitzgerald, 2018), the collected requirements showed that teachers' training and technical support are important aspects depending on the course. On the other hand, teachers participating in our research have vast experience with MR technologies, and the infrastructure is already set, facilitating the implementation of the modules and use of the hologram table. Another point highlighted in the analysis was that students and teachers are wishing for using innovative technologies in the lectures, to have more flexibility for teaching, learning, and working with real content, instead of abstractions.

Regarding the three conceptual modules, there were opportunities to support the lectures with game-based exercises varying from the presentation of content to team work. It would allow the direct participation of the students and improve social interaction. Advantages and challenges are also foreseen for the implementation of the modules. The 3D whiteboard can support a teacher-centered lesson and visualize complex models and

environments. It can be applied to larger groups of students and would connect with traditional teaching concepts. However, student-student interactions and collaboration may be relatively limited due to its visualization character. The application would also not be suited to train high-level skills such as evaluating or creating content. In the building game, the benefits of the module lie in the promotion of high-level skills like analyzing, evaluating information, and being able to create content independently. In this case, one requirement is the application of small-size groups to solve problems and create scenarios more efficiently, which could improve collaboration and student-student interactions. Finally, the game as a reward would require extra preparation from the teachers, demanding time, since they would need to cope with additional learning platforms. On the contrary, this module could reinforce the content learned and promote teamwork.

6. Conclusion and Outlook

A hologram table is a relatively new technology to explore courses' contents in an innovative way within university lectures. It should be implemented by taking teachers' and students' requirements into account while maintaining an effective learning environment. This study presented the concepts for three teaching modules to integrate a hologram table in mining engineering courses in agreement with users' needs and lectures' technical requirements. As the next steps of this research, the game-based exercises of each module will be defined together with teachers, the conceptual modules will be technically developed, and firstly tested in the courses of Applied Underground Mining and Applied Surface Mining. In addition, it is planned to adapt the teaching modules for use in medicine and dentistry courses, considering specific learning goals. Finally, some limitations on the hologram modules application are already foreseen, such as the adaptation to lectures with more than fifty students, the adjustment of the preparation time of projects, and gamified exercises according to the availability of teachers and the necessary technical support.

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Ingenious Game: Insights Into Evolving From a Learning Card Game to a Learning Software Application Game

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Abstract: Ingenious is a collaborative and competitive learning game application in which groups of students compete against each other in a product design and development (PDD) scenario where each group is responsible for a multidisciplinary team of engineers. The game has been used since 2020 to support a mechanical engineering master course. In this period, the game evolved from a card game to a software application. During the four game rounds representing the PDD phases, the players learn when to use over 80 different engineering design techniques. By choosing varying engineers and techniques, a student group creates a design strategy with a cost to execute and might be proven more effective than the competitors' strategies. Winning the game is about effectiveness in solving the challenges posed in the PDD scenario at a minimum cost. Once the game allows scenario customisation, new PDD scenarios can be created with different complexity levels. In the gamified classroom, grading is not a result of winning the game but a reflection of the group's choices and consequences while playing the game. This article presents the different game versions, describes the Ingenious game mechanics and dynamics and reflects on the game evolution and coverage of the Octalysis dimensions.

Keywords: Learning game, Octalysis framework, Product design and development

1. Introduction

Design problems are typically the most complex and ill-structured, for which solutions are achieved through an iterative process performed by a multidisciplinary team (Jonassen, 2015; Polman, 1998). The diverse engineering disciplines in a multidisciplinary PDD team use different tools and techniques (T&T) that must be efficiently combined to solve the design problem. Therefore, an important learning goal for future engineers is identifying the adequate design T&T combinations in each PDD phase to solve the specific design problem. With this motivation, Ingenious was developed for the gamification of PDD teaching.

This article aims to present the Ingenious game and provide an example of learning game mechanics and dynamics that can be used in other game scenarios where the collaboration of multidisciplinary teams is required to resolve a challenge.

2. The Ingenious Game Background and Development

The Ingenious game was developed to support using the need-based learning (NBL) pedagogical model in the context of modelling the technical design process (MTDP) course, which is part of the University of Twente's Mechanical Engineering Master programme. NBL is a pedagogical model for teaching PDD, which innovates by integrating just-in-time (JIT) learning, flipped classroom and gamification in a project-based learning setting. NBL includes six activities: challenge, select, acquire, apply, reflect, explain and evaluate (Pereira Pessoa et al., 2021). As depicted in Figure 1, a challenge is set by the lecturer, which becomes the background for all other course works. During the game phases, the students make a JIT selection of knowledge to be acquired in the flipped classroom, applying this information in the gamified project and reflecting on their choices and results. The lecturer then gives further feedback and makes the summative evaluation.

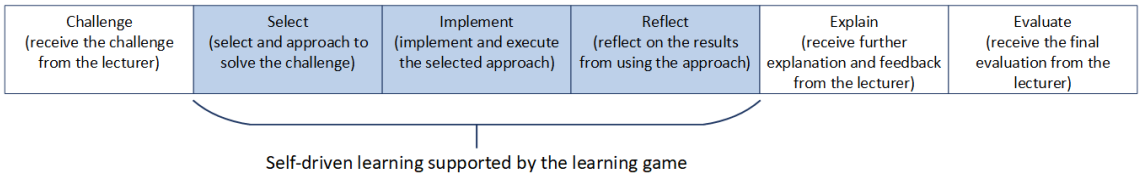

Figure 1: The Learning Game Supporting the NBL Pedagogical Model – Adapted From Pereira Pessoa, Oude Alink, et al. (2021)

The Ingenious game allowed the MTDP gamification, i.e. the use of game elements and game-design techniques in non-game contexts, thoughtfully applying typical game-like elements to real-world or productive activities (Díaz-Ramírez, 2020; Chou, 2016; Deterding et al., 2011; Werbach & Hunter, 2012). In this context, the Ingenious game aims at motivating and inducing desired actions to support an important subset of the MTDP learning goals:

- determining the appropriate PDD model (waterfall, iterative, spiral or agile), considering the product's technical requirements and uncertainty;
- defining the appropriate design and development T&T for each PDD phase, considering the disciplines needed during the process (e.g. mechanical, electronic and software);
- integrating the best practices for organisational process definition, engineering and engineering support into the PDD process according to the CMMI-Dev 1.3; and
- incorporating creative design techniques into the PDDP.

The Octalysis framework proposed by Chou (2016) was used during the Ingenious game design. Although other approaches for learning game design and gamification are available in the literature (Kapp, 2012; Zichermann & Cunningham, 2011), the main benefits of using Octalysis are its simplicity, clarity and abundant online information. Pereira Pessoa et al. (2021a) describe the rationale and choices behind the Ingenious game design. The Octalysis framework includes eight core drives that function as prerequisites for fostering motivation and triggering the planned behaviour: (1) **epic meaning & calling**, referring to when people believe they are doing something greater than themselves; (2) **development & accomplishment**, a drive to perform better, develop skills and achieve mastery; (3) **empowerment of creativity & feedback**, which is for players engaging in a creative process; (4) **ownership & possession**, motivating players by the feeling they own or control something; (5) **social influence & relatedness**, which incorporates the social elements that motivate people; (6) **scarcity & impatience**, a drive to want something simply because it is difficult to reach; (7) **unpredictability & curiosity**, which creates engagement because of the uncertainty of what comes next; and (8) **loss & avoidance**, the motivation to avoid a negative consequence. Although the Ingenious game has evolved from a card to a hybrid and finally a software-application game, all the versions incorporate the following elements, where the Octalysis' core drivers are underlined in the descriptions:

- The **game rounds** give **meaning** to the game by mimicking four phases from typical PDD (concept development; system development; detail development; and integration, verification and validation).
- The **challenge scenario** describes the development challenge that gives **meaning** to the game.
- The **risk level** contributes to the sense of **meaning**. The challenge scenario complexity indicates the risk level.
- The **die** adds an element of **unpredictability**. The die has different roles in the different versions of the game.
- The **result board** helps the team keep track of their progress. By visually representing the group's **accomplishments**, the board helps create **social pressure**.
- The **budget** is the amount of money spent. In all the game versions, there is no initial budget given to the teams, but they keep track of their accumulated costs. The budget adds **loss avoidance**, **scarcity** and **accomplishment** to the game.
- The **engineers** represent the different engineering disciplines of playing the game (mechanical, electrical, software, industrial design, production and systems engineering) that must be combined when resolving the challenge scenario. These cards provide meaning and a sense of **ownership**. Each player in the team is responsible for a different engineering discipline.
- The **T&T** represent design and development tools and techniques that can solve development issues according to their characteristics. The T&T contribute to the sense of **ownership**, as they are not the team's property but the property of each engineer, and only such engineers can play the T&T during a round.
- The **best practices** guarantee that the widely accepted best practices from PDD are also included in the game. Like the T&T, these cards help solve issues. But unlike T&T, the best practices are played by the team and not by a particular engineer.
- The **issues** represent typical issues from each PDD phase. A certain number of cards is randomly drawn in each round, contributing to the game's **unpredictability**. In the hybrid and app versions of the game, the issues became parts of the scenario, giving further **meaning** to the game.
- Finally, **empowerment** comes from the iterative rounds with design challenges, where previous play patterns would be to a team's advantage or disadvantage.

For playing the game, the class is divided into groups of students that compete against one another to create the most effective and least expensive PDD process. The groups must contain a maximum of six students so that each student is responsible for at least one of the six engineering disciplines included in the game. Although a single group can play the game, competition requires at least two groups, and there is no limit to the number of groups.

2.1 Ingenious 1.0: Card Game

The Ingenious game was initially developed as a card game, where the main inspiration was the game Munchkin® (Pereira Pessoa et al., 2021a). Using an existing game as an inspiration was an important factor to advance game development and avoid gameplay pitfalls. The idea was to create game mechanics where the warriors are the engineers, the weapons are the T&T, and the monsters are the typical challenges from the PDD phases.

During each game round representing a different PDD phase, the players execute three activities. First, they plan the round by selecting which T&T each engineer would use. After planning, they play eight challenge cards specific to the PDD phase randomly drawn from the challenge deck. A challenge is solved depending on the power of the played techniques. Finally, they have the last chance to identify and resolve unsolved challenges using the verification and validation (V&V) power from the T&T they planned for the round. Challenges that were neither solved nor reworked are carried to the next phase. Playing techniques and reworking have a cost, and the game objective is to solve all challenges at a minimum cost.

Figure 2 illustrates how Ingenious 1.0 is played. Both the T&T cards (1) and the challenge cards (2) have general traits (3) and specific traits related to V&V (4). Although solving a challenge might be possible using only one technique, a group of techniques often need to be combined to include all the traits required by the challenge. If two techniques in the set have the same trait, the one with higher power solves the challenge.

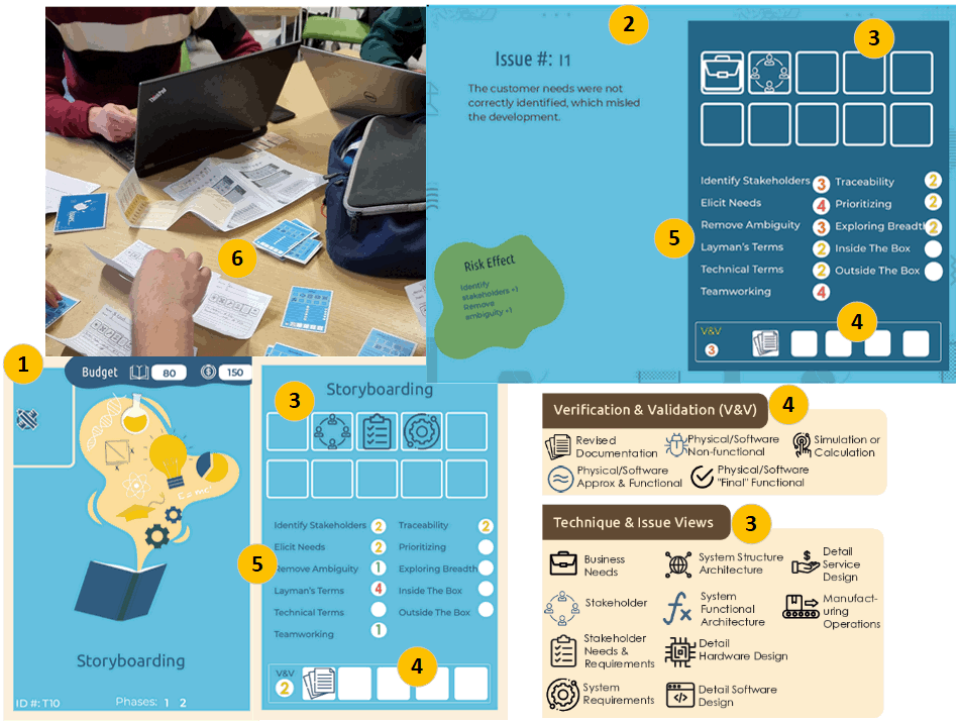

Figure 2: Ingenious 1.0

In this game version, the die adds unpredictability by giving a chance to trigger risks in each challenge card, increasing the power of some of its characteristics to be solved. If the challenge is not initially solved, it can still be reworked using the V&V. Finally, all the results from each round are annotated in specific sheets (6) to track the progress and compare the different teams' results.

This game version was played during the 2021 MTDP course. The 25 students in this cohort answered a survey, and qualitative feedback was also gathered during the gameplay. After playing this version of the game, the students' feedback was mostly positive; they particularly liked the dynamics the game brought to the class and reported being more motivated to come to class than for regular lectures. Some drawbacks of this version were mainly the generic nature of the challenge cards and the need for manual annotation. The defined challenges

were generic issues a team might expect to face during the different PDD phases, which did not reflect the specifics of the game scenario. The scenario used in this challenge was the development of an electric superbike. The mismatch between challenges and scenarios hindered the quality of the teams' reflection. The manual annotation was unwieldy and prone to errors, so it did not allow to define the winning team at the end of the game. Another interesting piece of feedback was that while the students liked the cards and the game, they considered the cards' manipulation sometimes confusing and unnecessarily time-consuming.

2.2 Ingenious 1.5: Hybrid Game

Considering the feedback received, a new version of the game was developed, one that no longer uses cards. In this version, the T&T and the annotation are done in an MS Excel® spreadsheet, and the issues are presented through an MS PowerPoint® presentation in a scenario-based narrative. In this new setting, the risk becomes intrinsic to the scenario (risk level) and succeeding or failing to solve challenges might decrease or increase the risk level, respectively. In this context, a dice result below the risk level value would implicate failing to solve the challenge, regardless of how powerful the chosen techniques were.

This version keeps the same four rounds, where the players perform a sequence of three activities in each round. To increase the need for strategy when playing the game, each engineering discipline has three engineers who can play only two T&T per round. In the first activity, the players decide which techniques each engineer knows. Since some T&T get a bonus from teamwork, the players must decide when to learn and play the same techniques by different engineers. In the second activity, the players plan which T&T to play in the round from the T&T already learnt by the engineers. The fact that some T&T can be played in more than one round further requires planning for which T&T to learn. The third activity includes following the deployment of the presentation scenario and related challenges, throwing the risk die to confirm solving each challenge and inputting the result in the MS Excel® spreadsheet. The last activity in the round is the V&V, where unsolved challenges can be reworked at an additional cost. Challenges that were neither solved nor reworked are carried to the next phase. Winning the game is about having fewer unsolved challenges at the end. In the case of a tie, the first untie criterion is lower cost, and the second criterion is more techniques learnt. Figure 3 shows the learning sheet (1), the concept development planning sheet (2) with the already learnt techniques marked in yellow for difficult mistakes and the playing sheet (3). The playing sheet (4) already carries the maximum value from the T&T (5) at play and calculates all the results (6).

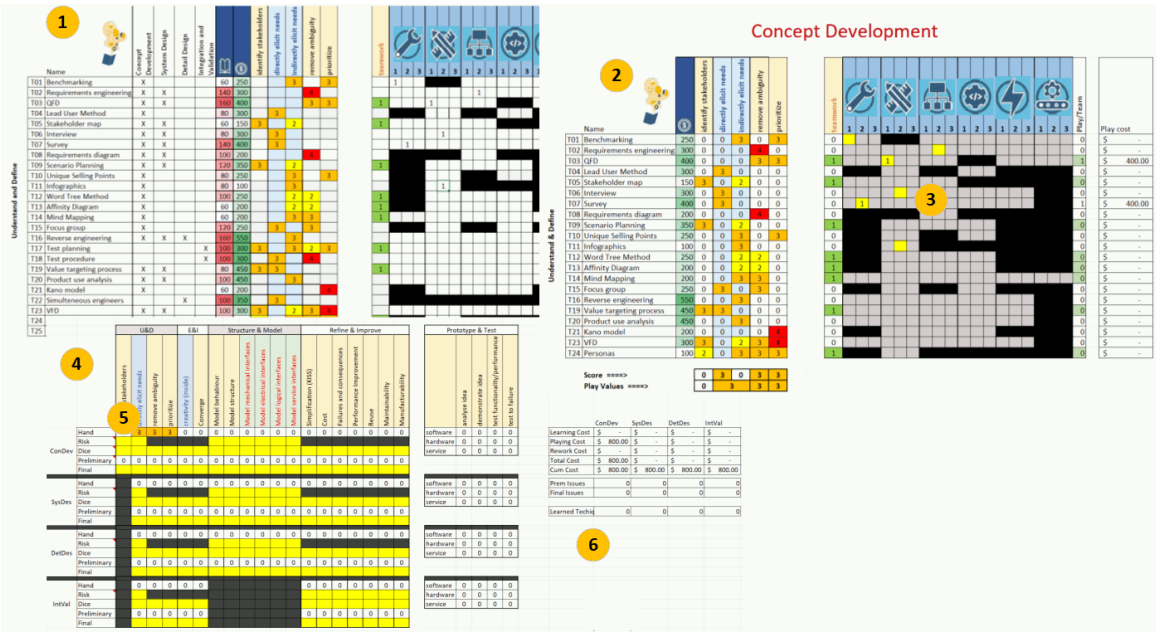

Figure 3: Ingenious 1.5

This game version was played by 39 students during the 2022 MTDP course. The students' feedback pointed again to the game's positive motivation to come to class. Working together facilitated the possibility of sharing the spreadsheet and solved the card manipulation issue. Using a scenario presentation where the challenges were unfolded as part of the narrative increased fidelity between the challenges and the scenario. The increased reliability also improved the quality of the team's reflection on their choices. It achieved results during the

gameplay, which is essential because the course grade is based on this reflection's quality rather than on winning the game. The locking and validating of cells in the spreadsheet almost eliminated the errors, and the winning team was easily identified, which gave a nice closure to this part of the course.

When playing this version, some groups worked on optimising their round choices by combining the T&T with higher trait values. It sometimes led to a strong combination of T&T that would not be used in a real-case scenario. During the feedback, the students highlighted that this issue negatively impacted the full achievement of the course's learning goals. Besides this critical point, they suggested that the engineers should already know some basic T&T.

2.3 Ingenious 2.0: App Game

After the experience from playing version 1.5, it was considered that the game format was mature enough to reflect the last feedback and become a software application. This version was developed in a project partnering with Stichting GameLab Oost (gamelaboost.nl/) and had the main objective of turning the Ingenious game into a learning game application, which included further good practices of game development and comprised creative solutions to approach the opportunities of improvement identified when playing version 1.5. The main changes included creating a software application with a coherent look and feel, covering all the relevant information for playing the game and calculating the team's results. While the app embeds most of the game mechanics, it was decided that the unpredictability risk and use of physical objects (dice) would be left outside the software application. The objective was to create interaction among the players outside of the computer screen.

Based on the previous feedback, the following aspects were considered:

- To further guarantee the learning goals' achievement, the T&T's trait values were hidden from the players. Consequently, the players must select the T&T based on their theoretical capabilities instead of selecting them based on their trait values.
- To increase the game fidelity, the learning activity was removed, and the engineers gained three seniority levels (junior, medium or senior). In each round, the group can play with up to one engineer from each discipline, who can be junior, medium or senior. The higher the seniority becomes, the more advanced T&T the engineer can play, but the higher the T&T playing cost gets (senior engineers cost more). There is no limit to the techniques an engineer can play per round, and some techniques have a bonus if played by a multidisciplinary group.

Other important requirements for the game app were the flexibility for changing the scenario and the related challenges, updating the traits and characteristics' values from the T&T and the possibility of adding new T&T.

3. Playing the Ingenious 2.0 Game

Ingenious is played over four rounds, relating to different PDD phases. These phases are concept development, system design, detail design and integration and validation. In each phase, the gameplay includes a planning stage and a playing stage. During the planning stage, the group defines which T&T will be played during the phase. The playing stage can start when the group is satisfied with the T&T selection. At the start of the playing stage, the T&T selection is locked, and the development challenges are presented in sequence. The last step of the playing stage relates to V&V activities when the group can uncover and correct (rework) issues from unsolved or partially solved challenges. Any remaining issues are carried as **hidden problems** to the next phase. The remaining issues from the integration and validation phase end up in the hands of the customer.

Planning Stage

Figure 4 shows the planning stage screen. To reduce the amount of information on the screen, the T&T were divided into categories. The figure shows the Refine & Improve category T&T playable by different engineering disciplines according to the chosen engineering seniority. Some T&T have a teamwork bonus, which means they become more powerful if two or more engineers play this same T&T during the same round. By keeping track of the current budget expenditures, the group can view the financial consequences of different choices of T&T and engineers.

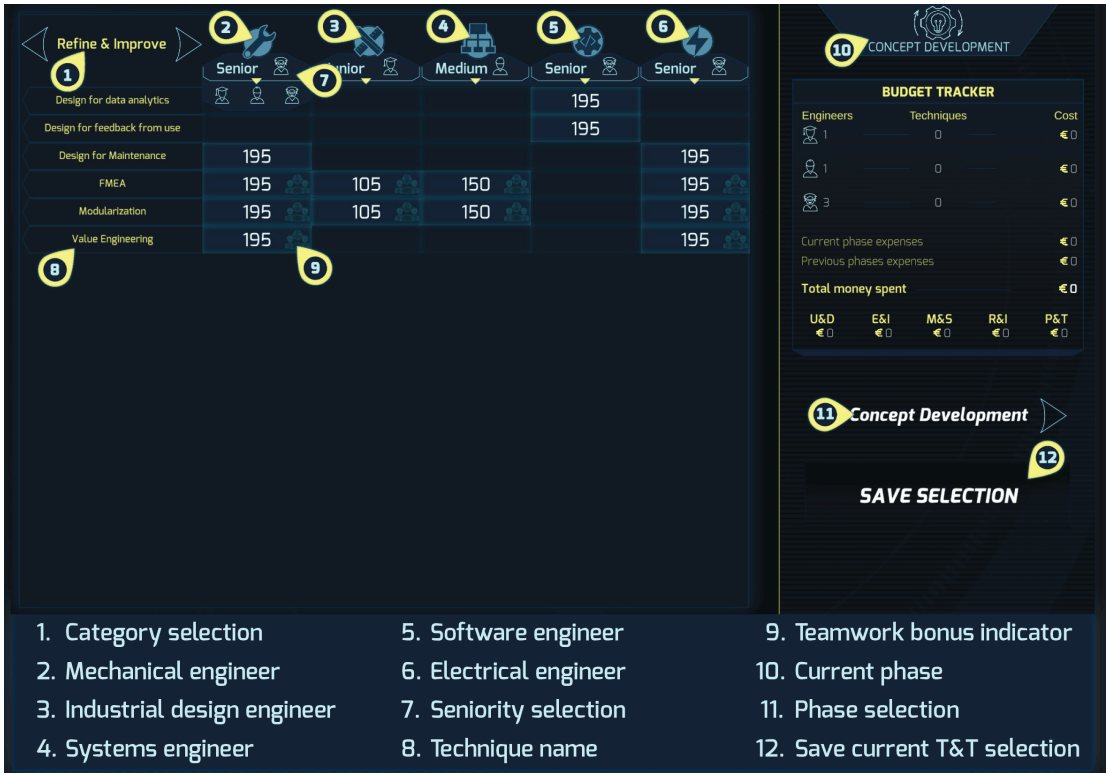

Figure 4: Ingenious 2.0 – Planning Stage Screen

Playing Stage – Steps for Preventing Issues From Challenge Failure

After selecting all the techniques to be played during all rounds, the plan is locked, and the scenario is loaded to play. The challenges from the scenario are presented in sequence, and the group checks if their T&T choices are good enough to solve the challenge, preventing the consequences of failing it. Figure 5 shows a sample screen where a challenge is described. On the left side, the team can see the chosen T&T score in the traits required to solve a challenge and if they also selected the PDD best practices that influence the challenge. Based on the points they accumulated by the chosen T&T and best practices, the number of green tokens is calculated, and based on the challenge's difficulty, the number of red tokens is measured. The group put the physical green and red tokens in a bag, shuffle the bag and pick one token. If the token is green, they have solved the challenge; if it is red, they have failed.

Playing Stage – Steps for Reworking Open Issues From Failed Challenges

At the end of each round, the group can solve issues from failed challenges and avoid carrying them to another round. This part of the playing stage represents the V&V activities that normally happen at the end of any PDD phase. This way, issues not prevented by a good design can still be detected and corrected during the tests. Figure 6 shows the screen where open issues from unsolved challenges are presented. Depending on the quality of the T&T planned for V&V, the player can discover and perform rework that solves open issues. The number of times the players can throw the die is based on their strategy quality. A special die is used here, with values 0, 1 or 2 only.

After throwing the special die and getting the number of issues that can be solved, the group can resolve open issues from the actual or previous rounds. The rework cost for solving an issue from the round in play is €500, but this cost increases in the case of previous rounds. For instance, reworking an issue from CD will cost €1000 during the SD phase, €2000 during the DD phase and €4000 during the IV phase.

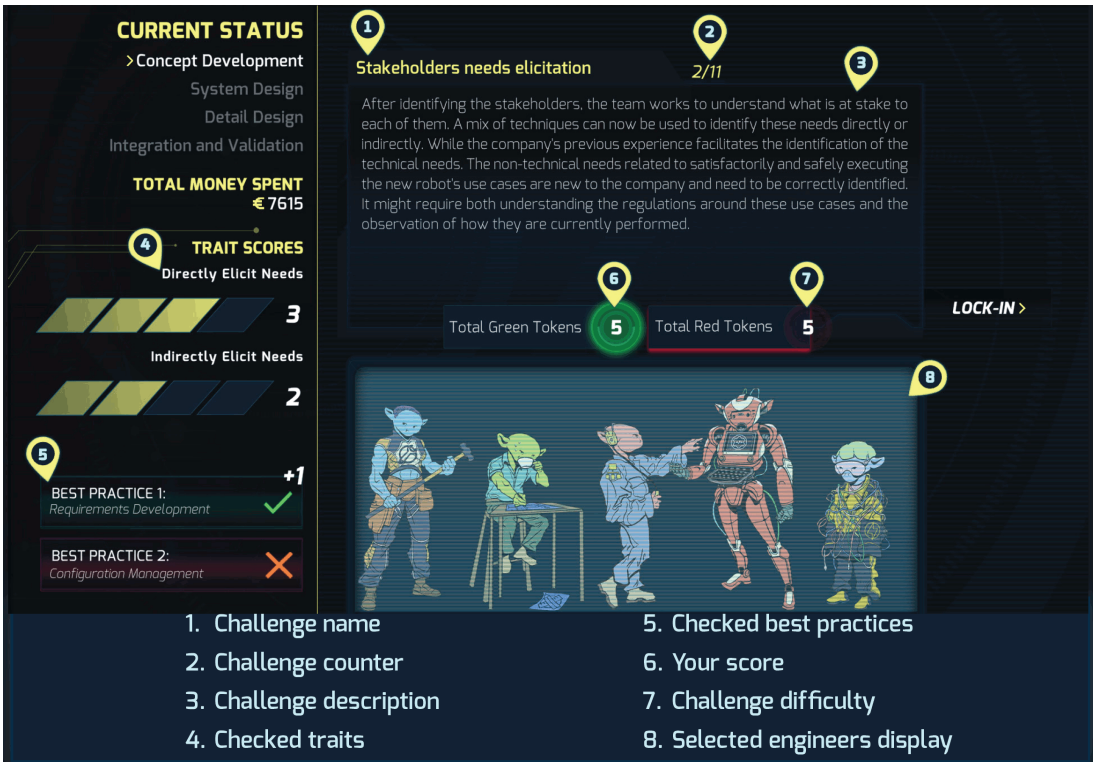

Figure 5: Ingenious 2.0 – Challenge Solving Screen

Figure 6: Ingenious 2.0 – V&V and Reworking Screen

Checking Results

Figure 7 shows the overview screen, where the results from each round can be revised. Here the group can check which techniques they played per round, how many challenges issues were solved, how many issues were resolved or remain open, the round expenditures and the total expenditures. The group can work on their reflection report using this information and after reviewing the challenges.

All this information is also exported to an Excel file the lecturer can use to compare the groups and define the winner.

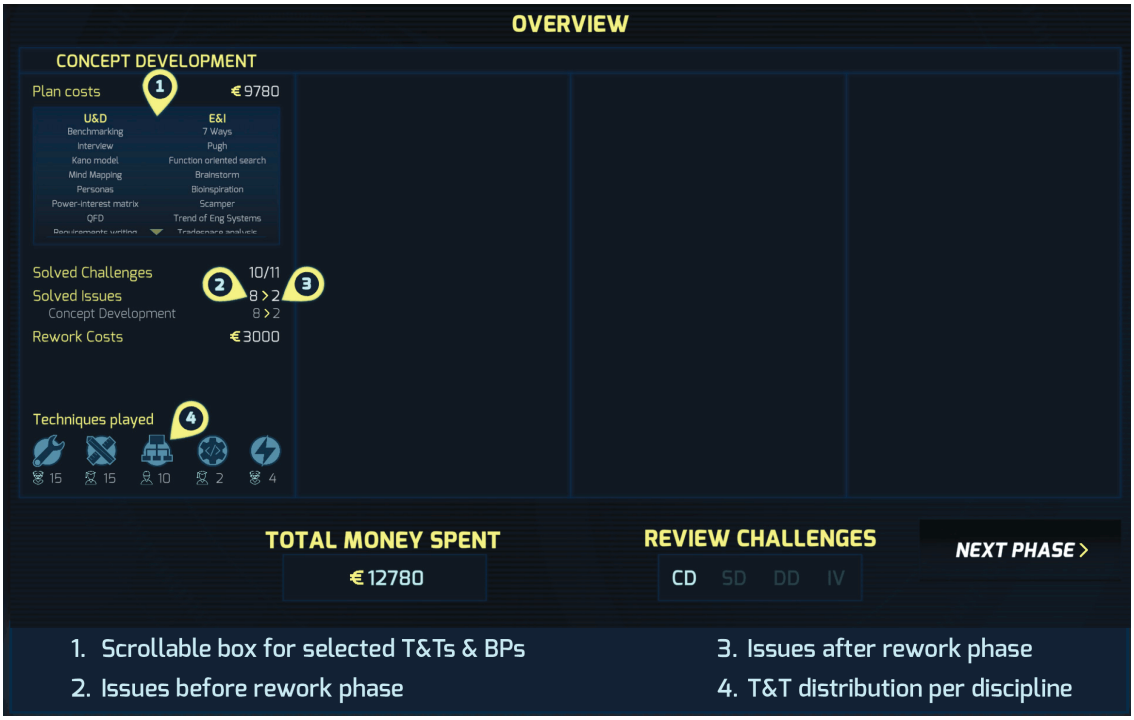

Figure 7: Ingenious 2.0 – Overview Screen

4. A Reflection on the Ingenious Game Evolution

During the Ingenious game evolution, the game elements were adjusted to support the learning goals' achievement better and deliver a better gameplay experience for the students. Table 1 summarises the drivers and results of these changes. The gameplay improvement was analysed using a Pugh chart, where the criteria are the dimensions from the Octalysis. The improvement in supporting to achieve the course's learning objectives was based on the students' feedback. Note that the Ingenious Game 2.0 was tested in pilot groups but has not yet been used during the MDTP course.

In Table 1, Ingenious 1.0 is used as a reference, and the other versions are compared to it. Therefore, ++, +, 0 and – relate to being better, equal or worse than 1.0. Consequently, these are not absolute values, which means that ++ does not imply the version has a great implementation of that specific dimension but solely that it is much better than 1.0. Giving absolute values to the dimensions would require comparing the Ingenious game versions to other games, which is outside this work's scope.

Table 1: A Reflection on the Ingenious Game Evolution

Criteria	V1.0	V1.5	V2.0	Comments
Epic meaning & calling	0	+	+	While the challenges in v1.0 were generic cards, which did not necessarily reflect the scenario, the challenges in v1.5 and v2.0 became specific to the scenario (the game fidelity was increased).
Development & accomplishment	0	+	++	As the game fidelity increased, the sense of accomplishment became clearer.
Empowerment of creativity & feedback	0	0	0	Feedback was based on whether a challenge was solved. In all the versions, each game round was played only once, and the empowerment was limited to the experience gained from playing the previous round.
Ownership & possession	0	0	–	Ownership and possession were related to the engineers and the techniques they could play. This dimension was more potent when using the cards and when the engineers learnt techniques (possessed knowledge).

Social influence & relatedness	0	0	0	In all versions, social influence was based on the players competing as a group against other groups. In this sense, there was social influence among group members.
Scarcity & impatience	0	0	0	Although there was no predefined budget, the scarcity sense was given through the objective of minimising the total money spent during the rounds.
Unpredictability & curiosity	0	+	++	Unpredictability was presented by not knowing which challenges might arise in one game scenario and the possibility of the risks increasing the challenge difficulty. Unpredictability improved in the different versions of the game to bring challenges and risky conditions closer to the real case scenario.
Loss & avoidance	0	+	++	Loss and avoidance were illustrated by avoiding rework penalties, which were always more severe than the cost of solving the challenge directly. This required the players to prioritise balancing the conflict between minimising expenditures on T&T to be played and lowering the chances of rework. By using an app, the rework penalisation was greatly improved and became more transparent.
Learning goals achievement support	0	+	++	Both automation and fidelity increased through the versions. The former reduced the chances of errors, and the latter brought the game closer to reality. These changes combined led to game mechanics and dynamics that better fulfilled the course's learning objectives.

5. Final Remarks

This article presented the Ingenious learning game, developed to facilitate the teaching of how to choose a good set of design T&T to be used by different engineering disciplines and where these T&T must be efficiently combined to solve the design problem. The Ingenious game is in version 2.0, based on a software application and some physical elements to promote interaction among the teams playing the games. Its first version (1.0) was a card game inspired by the commercial leisure game Munchkin®, and its second version (1.5) used MS Excel® and MS PowerPoint® to simplify the gameplay and facilitate the game score calculation. The insights from this game development journey included the following:

- There is a benefit to having a previous and tested game as inspiration to accelerate the initial game development and reduce the risk of poor gameplay.
- Using a widely accepted game-creation framework to reduce the chances of designing an imbalanced game with poor fun and engaging factors is advantageous. The Octalysis considered and helped balance the eight core drives that function as prerequisites for fostering motivation and triggering the expected learning behaviour.
- Creating a physical version of the game instead of directly developing a computer version is beneficial. A physical game is more flexible to try small variations from the game mechanics and dynamics (e.g. adding elements or modifying the rules). Software development takes time, and constant changes in requirements delay the development and increase the risk of inconsistencies.
- Getting feedback from the students is essential. Regardless of the game framework used, the players (the students in this case) are the ones that can best rate the game quality. In this journey, the student feedback was critical towards understanding how the game could support the learning objectives.

Although the Ingenious game was developed in the context of design problems and PDD scenarios, its game mechanics and dynamics can be generalised to other situations that benefit from the collaborative work of diverse specialists, which use specific T&T to solve a common problem. In this sense, the work presented here can be used as inspiration to other game developers. Future work, therefore, includes possible expansions towards other scenarios where professionals' collaborative work with different disciplines is required to solve a challenge successfully.

Acknowledgements

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Number Express: A Digital Game to Improve Early Numeracy

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Abstract: Early numeracy (including basic skills like counting, order processing, etc.) has repeatedly been observed to predict later scholastic but also vocational prospects. As such, it seems sensible to foster it early on during development. In this article, we describe the development and initial evaluation of *Number Express*, a digital game designed to facilitate numerical skills in pre-and primary school considering the latest evidence from research on order processing. The game consists of a train with six carriages for the player to fill in with numbers in the correct order. The game progresses in difficulty across several levels, moving from smaller to larger numbers and sequences in steps of 2, 5, and 10. Informative feedback helps players in case they respond wrongly. Associating numbers to carriages in the correct order earns the player points, with which they can buy items in a virtual shop, providing additional experience with calculating with money. During the design phase, we sought feedback from researchers, teachers, and an education consultant specialising in the learning and teaching of primary mathematics. Piloting will involve testing the game with a small group of preschool children to evaluate its playability and ease of use and to resolve any remaining technical issues. Additionally, we will gather feedback from children to identify any areas of the game that might be improved or made more engaging. In the next step, the game will be implemented in an intervention study to determine its effectiveness in improving children's early numeracy skills. In case the game proves to be effective in improving children's early numeracy skills, it has the potential to be a valuable tool for educators and parents in supporting their children's numerical development.

Keywords: Digital game, Number ordering, Preschool and primary children, Early numeracy

1. Background

Basic numerical skills are the foundation of more advanced maths skills (Watts et al., 2014) and significantly predict future mathematical learning and scholastic achievement (e.g., Atkinson et al., 2022; Duncan et al., 2020; Davis-Kean et al., 2022; Jordan, Hanich and Kaplan, 2003; Duncan et al., 2006). Around the age of two years, children begin implementing counting routines to learn the cardinal meaning of number words so that "one" represents a set with one item, "two" a set with two items, etc. (Gelman and Gallistel, 1978; Sarnecka, 2015 Sarnecka, Goldman and Slusser, 2015). Children progressively create an association between specific number words and specific numerosities in terms of symbol-magnitude associations. Children also learn that number words reflect ordinal relations depending on their position within the sequence of symbol-to-symbol association; they need to understand the ordinal relations among digits, for example, that 5 comes after 4 and before 6 (Sasanguie and Vos, 2018). Additionally, numbers can be spatially represented in order on a number line where the position of a number provides information about its magnitude and ordinal relation as argued for cartesian axes (Sella et al., 2017).

Not surprisingly, many intervention studies make use of games and activities to consolidate ordinal relations between numbers but also cardinal understanding of number magnitude by fostering children's skills in correctly locating numbers on a number line (e.g., Siegler and Ramani, 2008). With the increasing availability of touch-screen devices such as cell phones, tablets, etc., games and apps have been implemented to facilitate children's learning, including topics in mathematics and science (Klawe, 1999; Annetta et al., 2009; Sella et al., 2016; Sella et al., 2021). Besides acquiring subject-specific knowledge, such digital games also seem to increase students' motivation and promote positive attitudes towards learning (e.g., Ke, 2009; Pareto et al., 2011; Crittenden, Biel, and Lovely, 2019). The game "The number Race" (http://www.thenumberrace.com/nr/home.php) is a well-known example of a digital game that was based on solid research evidence (Wilson et al. 2006; Rasanen et al., 2009; Sella et al., 2021) and that has several evidence of its efficacy (Sella et al. 2016). The game supports multiple numerical skills, such as comparing symbolic and non-symbolic numerical quantities, counting, and simple arithmetic. The same research group developed another digital game, Number Catcher, (http://www.thenumbercatcher.com/nc/home.php) to foster basic calculation skills, the base 10 principle and

the logic of multidigit numbers. Even though these games support basic numerical skills, they do not specifically target number order skills. There is increasing recent evidence that number order skills are crucial for the development of early numerical skills. Moreover, a search on google scholar with the keywords "number ordering and game" did not bring us back useful results. Therefore, we decided to create a game with a clear theoretical connection to number order.

Considering these background aspects, this manuscript describes the development of the app "Number Express" intended to facilitate early learning of numerical order by requiring children to place numbers in the correct order on a number line.

Here, we will present the main conceptual characteristics of the game and initial feedback on its usability by numerical cognition researchers and educational practitioners before we briefly discuss the next development steps in piloting the game and evaluating its effectiveness in an intervention study.

2. Conceptual Characteristics of the Game

2.1 The Theme and Game's aim

The narrative of Number Express is situated in a train station where the train conductor has to renumber carriages of an incoming train because some carriage numbers have fallen off. The train has six carriages, some of which still have their number label on (serving as reference points for numbering the other carriages), while others do not (reflecting target numbers to be allocated by players).

When starting the game, children first choose between different animal characters representing the train conductor they want to play with and type in their name (see Figure 1).

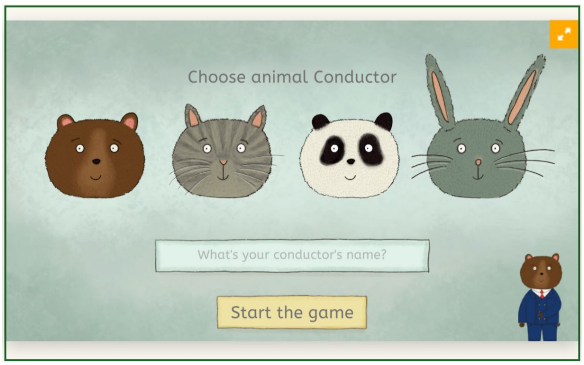


Figure 1: Starting screen to choose the character of the train conductor

Then, the train arrives on the screen, and a target number (to be associated with one of the unlabelled carriages) is shown at the top-left of the screen together with the sound of the respective number word reflecting the association between visual and verbal representations of the respective number (e.g., "four"; Figure 2). The player then has to drag the presented target number to the respective carriage, considering the given numbering on the other carriages as references or simply click on the chosen carriage.

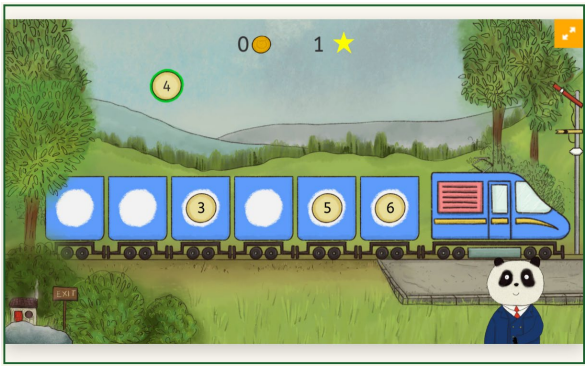


Figure 2: Main gameplay screen showing the train with already numbered carriages. The number 4 with a green circle around it is the number that the player has to put on the right carriage. At the top of the screen, the number of coins earned by the player is given (the number next to the coin image) as well as a number identifying the current level (the number next to the star) and the number of

rounds a player has played within a level (the star indicates that this is the first round played. When the player plays the second round there are two stars on the screen and so on). Each level has five trains. The button "exit" (the sign on the bottom left of the screen) leads the player to exit the game. The button "home" (the little house depicted on the bottom left of the screen) leads the player to the game's homepage

After associating the first target number with a respective carriage, the next one will appear until all carriages are numbered. At that point, the locomotive shines, and children can click on it to make the train leave the station. In case target numbers were associated with carriages to reflect a correct order (e.g., 1, 2, 3, 4, 5, 6 in Figure 2), the train leaves the station and another train appears on the screen. When some of the numbers are not in the correct order, the train does not leave the station and the numbers which are on the wrong carriages will be moved to the top of the screen and informative feedback appears on the screen. If the player put the numbers in the wrong carriages the first feedback that they receive is a visual and verbal message (Good try! Some of the numbers are not in the right place), and then they can try again to put the number on the right carriages. If they put the numbers in the wrong place again they receive the same message and a number line appears under the train. Then, the player can use the number line to copy the position of the numbers (See paragraph 2.3 and Figure 4 for more information on this game's informative feedback). For every train the player makes leave, they are awarded one coin as a virtual incentive. After five trains successfully leave the station, the player will have five coins to spend in a virtual shop (Figure 3) allowing them to buy accessories for the train (e.g., stickers to decorate the train or the possibility to change the shape of the train) and clothes or accessories for the train conductor (e.g., a new outfit, a hat or a toy). To pay in the shop the player can only use the virtual coin earned playing the game. They can also change the train conductor character for free (e.g., panda, bear, cat, and rabbit). Once they are done with their shopping, they can return to playing the game.

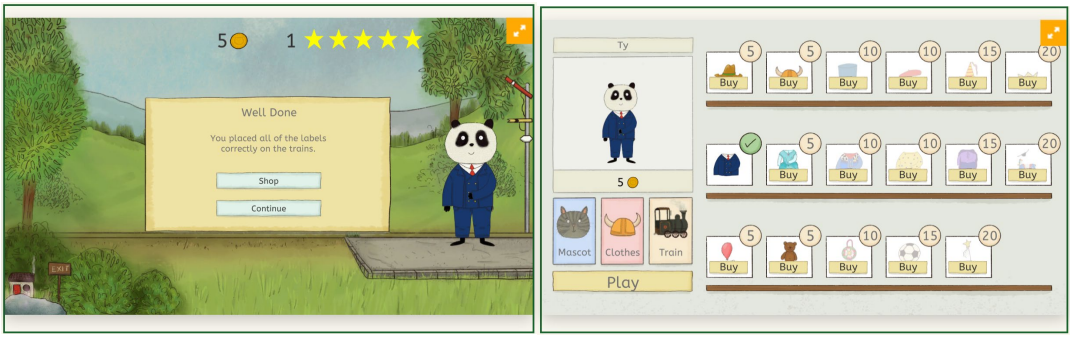


Figure 3: The shop. On the left is the screen where the player can choose to go to the shop or continue playing. In the latter scenario, the player will continue accumulating the coins earned during the game. On the right is the screen of the shop. The player can see their train conductor with their name, and the amount of virtual coins they can spend in the shop. Once they have completed their shopping the amount of money will change accordingly. The button with the label "Clothes" depicted allows the player to see all the goods they can buy for the train conductor. The button with the Mascot depicted allows the player to change the train conductor for free. The button with the Train depicted allows the players to see all the accessories they can buy for the train

2.2 The Levels

The game comes with 118 levels of difficulty, which mainly vary depending on the number range and the respective reference numbers already on the carriages. For instance, level 1 only involves numbers between 1 and 6 with three reference numbers given, whereas level 60 involves numbers between 71 and 76 with only one reference number. Each level involves 5 rounds (5 trains with all the carriages labelled).

It is possible to start the game at seven starting points (Table 1) for levels operating on the same numerical content (i.e., number range, counting in 1s, 2s, decade crossings, etc.) and thus difficulty. The starting points align with the UK Curriculum (Department for Education, 2021) reflecting that during the Early Years Foundation Stage, children up to 5 years (Reception year) should learn to verbally count beyond 20 (reflected by starting point 1), and recognise the pattern of the counting system (e.g. even numbers patterns: 2 ,4, 6,….; odd number patterns: 3, 5, 7,…reflected by starting point 2). Children in Year 1 should learn to count, read and write numbers up to 100 in numerals, count in multiples of 2s, 5s and 10s, as well as identify and represent numbers using pictorial representations, including the number line (Department for Education, 2021). This is reflected in

starting points 2 to 7, in which children have to count in multiples of 2s, 5s, and 10s within the number range of up to 119 involving or not involving decade crossings.

This way, the game facilitates children's understanding of the ordinal and spatial relations between numbers (symbol-to-symbol association) by working with number lines while also strengthening the association between Arabic numbers and the corresponding number word (e.g., 10 = "Ten"). Children can learn to count in 2s, 5s, and 10s, while exploring the number range from 1 to 120, including trials involving decade crossings. Additionally, children practise some arithmetic when buying items in the shop although this is not the primary learning goal of the game. All these features make the game align well with the aims of the UK curriculum for the Early Years Foundation Stage and Year 1.

Table 1: Starting Points of the Game

Starting points	Levels	Numerical Content
starting point 1	1-10	Counting in 1s between 1 and 20
starting point 2	11-17	Counting in 2s between 2 and 24
starting point 3	18-24	Counting in 10s between 10 and 120
starting point 4	25-31	Counting in 5s between 5 and 60
starting point 5	32-38	Counting in 2s odd numbers between 1 and 23
starting point 6	39-78	Counting in 1s between 21 and 119 not crossing tens
starting point 7	79-118	Counting in 1s between 27 and 123 crossing tens

2.3 Adapting the levels to players' performance algorithm

Irrespective of the starting point chosen, we implemented an adaptive algorithm to determine the player's progression through the game. The algorithm keeps the player in a zone of optimal challenge by presenting more difficult levels in case of a given number of correct responses and easier levels in case of incorrect responses (see Table 2a and Table 2b for details). An incorrect response is when the player put the number on the wrong carriage. The train will not leave the station unless all the numbers are on the right carriages. There is no time limit for the player to correct their responses. For players that commit two or fewer errors, there is a 10% chance they play rounds on the same level, a 60% chance they go to the very next more difficult level, a 10% chance they go to two levels up and a 5% chance they go three levels up. For players who give two or more incorrect responses, there is a 60% chance they play rounds on the same level, a 25% chance they go to the previous level, a 10% chance they go two levels down and a 5% chance they go three levels down.

Table 2a: The adaptation algorithm in case of ≤ 2 incorrect responses in a round (each level has 5 rounds. The algorithm decides the difficulty of the next round based on the present round player performance.)

In case the player had ≤ 2 incorrect responses (i.e., clicking on the locomotive to leave the station, but numbers were not in the correct order) in the current round, the algorithm will direct the player to a specific level for the next round with the following probabilities.					
Next Level	L-1	L	L+1	L+2	L+3
Percentage of next-level selection	0%	10%	60%	25%	5%

Table 2b: The adaptation algorithm, in case of >2 incorrect responses in a round (each level has 5 rounds. The algorithm decides the difficulty of the next round based on the present round player performance.)

In case, the player had > 2 incorrect responses in the current round, the algorithm would direct them to a specific level for the next round with the following probabilities.					
Next Level	L-3	L-2	L-1	L	L+1
Percentage of next-level selection	5%	10%	25%	60%	0%

2.4 The Motivation Game's Elements

Malone (1980) described three elements that can make a game fun, and increase intrinsic motivation: *challenge*, *fantasy*, and *curiosity* (Malone, 1980). To be motivating, a game needs to present a challenge to the player with goals and uncertain outcomes, that can engage a player's self-esteem. Moreover, fantasy (i.e., a game can stimulate a player's imagination with its story) can make a game more interesting because the game can evoke images of scenarios, situations or objects that can engage the players. Lastly, a game is more engaging if it stimulates players' sensory, and cognitive curiosity, with novel and surprising content. According to Malone's taxonomy, we considered some of these elements when designing the game.

The adaptative algorithm manipulates the difficulty level to keep the player in a constant zone of optimal challenge. Moreover, the algorithm adds a surprise element as children who respond always correctly in a round may suddenly face much more difficult levels. It is important to notice that this surprise of being presented with much more difficult levels does not apply to children who are already struggling with the current level to avoid any frustration. Another element that makes *Number Express* challenging is its *goal.* Number Express's goal is to label the carriages to allow the train to leave the station. When players do this correctly, they earn virtual money to spend in the *shop*¸ which could be considered an additional goal itself. Children's desire to personalize their avatars and thus buy items in the shop could further motivate children to play the game for longer. Moreover, buying items in the shop offers more opportunities for learning mathematics, such as comparing the cost of an item to the money a player has and calculating how much more money is needed to buy a specific item.

In designing this game, we hired a professional graphic designer to create illustrations that can stimulate children's fantasies. We also chose to present shop items that are frequently liked by both boys and girls. The detailed background and the possibility of choosing and naming their character to play the game should also further stimulate children's fantasy and immerse them in the game's narrative.

To stimulate cognitive curiosity, we implemented a *two-stage informative feedback system.* In particular, when the player puts the numbers on carriages in the wrong order, the wrongly ordered number labels move to the top of the screen, and a visual and vocal message appears to inform the player that the indicated order is not correct (i.e., stage 1, see Figure 4, left chart). At this point, the player can associate the numbers with carriages again. In case, the player gets the order wrong again, a number line will appear under the train so they can use it to order the number correctly (i.e., stage 2, see Figure 4, right chart). Stage 2 shall guarantee that all children can place the numbers in the correct order by matching the numbers on the carriages to those on the number line. This feedback provides players, including those struggling with number order, with enough information to order the numbers accurately (Figure 4).

Overall, the game's goal and the adaptative algorithm make the game *challenging* for children. The visual aesthetics and the narrative activate children's *fantasy* of being the train conductor who needs to make the train leave the station. Finally, the two-step informative feedback system gives children enough information to complete the task at hand.

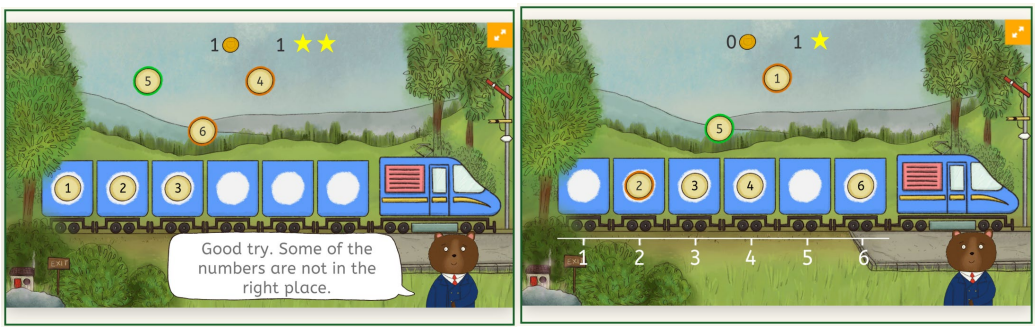


Figure 4: The two-level informative feedback system

3. The Designing of the Game

To design the game Number Express, we reviewed the literature on number ordering skills (Devlin et al., 2022; Sasanguie & Vos, 2018; Sella et al., 2020) and on what makes a digital game engaging for children (Malone, 1980; 1981). We considered studies on the importance of the number line as a tool to spatially represent numbers in number games (e.g., Siegler & Ramani, 2008). This evidence guided us in designing the game. Accordingly, the numbers on the screen are presented in a linear order equidistantly and with numerical magnitude increasing from left to right (i.e., 1-2-3-4…) and we set the levels of difficulty according to the national math goals in the UK. Moreover, we asked a professional graphic designer to create the game scenarios and characters mimicking

the style of popular books in nurseries and primary Schools in the UK to ensure the illustrations were familiar to the children and suitable for their age. Finally, the first version of the game was modified according to the received feedback as described in the paragraph "Initial feedback".

4. Evaluation of the Game's Usability

4.1 Initial Feedback

After the first version of the game was prepared, we sought feedback from academic colleagues with a cognitive and pedagogical background, a primary school teacher, and an educational consultant specialising in the teaching of mathematics in Early Years.

They all expressed great interest in the game and evaluated it very positively. They found the game engaging and reported that the learning goals are clear and linked to the UK curriculum.

They suggested offering the possibility to choose the game's level of difficulty and the number range to play with at the beginning (now implemented). The screen with the possibility to select the starting point prevents players from getting bored of playing from the beginning with the easy levels before getting to the challenging ones. Moreover, they suggested presenting larger number intervals from 20 to 120 without crossing the decade before the same intervals are presented with the cross of a decade.

After the piloting phase (see next paragraph), we foresee additional changes to be made before moving to test the effectiveness of the game in a randomised controlled trial.

4.2 Piloting Phase

In the piloting phase, we aim to evaluate the game's usability as "a quality attribute that assesses how easy user interfaces are to use" (Nielsen, 2012, paragraph 1). Accordingly, the usability of a system can have five components (Nielsen, 2012): learnability (e.g., how easy it is for users to accomplish basic tasks the first time they encounter the game), efficiency (e.g., once users have learned the game, how quickly can they perform tasks), memorability (e.g., when users return to the design after a period of not using it, how easily they re-establish proficiency), errors (e.g., how many errors users make, how severe these errors are, and how easily they recover from the errors), and satisfaction (e.g., how pleasant it is to use the game). Following this definition, we developed an observation checklist and an interview-based questionnaire for children to test Number Express's usability.

We plan to recruit children aged 4 to 6. Children will play the game individually on a tablet during regular school hours. Trained research assistants will support children in playing, fill in the observation checklist (Table 3), and, at the end of the game session, ask children a few questions about their user experience (Table 4). The research assistants' interaction with children will be kept to a minimum resembling future user contexts in which teachers will set up the playing session for many children.

The observation checklist will allow us to evaluate the game's learnability, efficiency, and errors. We will not assess memorability during the piloting phase, as children will play only once. We will evaluate players' satisfaction through the interview-based questionnaire (Table 4).

Table 3: The observation checklist

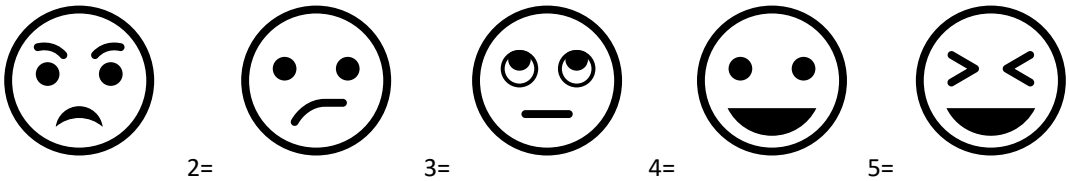
COMPONENTS	INDEXES
Learnability	The child needs to see the video tutorial again or ask the adults for help. How many times?
Effectiveness	The child understands how to start the game.
	The child can select the train conductor.
	The child doesn't need help to write the train conductor's name.
	The child knows how to move the number tag through the screen.
	The train understands how to make the train leave.
	The child understands how to enter the shop.
	The child can buy items in the shop.

COMPONENTS	INDEXES
	The child can come back to the game after having been in the shop.
Error	Frequency of the errors. How many?
	The child knows how to correct themselves.
Efficacy	The number line helps the child to put the number in the right order.

We will evaluate players' satisfaction using an interview based questionnaire (adapted from Ismail et al., 2011).

Table 4: The interview-based questionnaire

Questions to the player
1. The game was fun.
2. The game was easy to play.
3. I like the game characters.
4. I want to play this game again.
5. I would like to play this game at home.
6. I would recommend this to a friend.



1= 2= 3= 4= 5=

5. Conclusion and Future Perspectives

Number Express is a digital game designed to support basic numerical skills in pre-and primary-school children. We designed the game to accommodate crucial aspects of basic numerical development such as ordinality, the spatial representation of numbers (i.e., number line), and counting in 1s, 2s, 5s, and 10s. To facilitate the learning process while playing, we implemented informative feedback which also makes sure that children can correctly complete each trial and gain coins to keep them motivated and avoid frustration. Finally, the possibility to buy accessories in the virtual shops through the coins awarded should also motivate children to keep playing. Additionally, the latter should also entail additional mathematical experience by requiring them to calculate the money to be spent. The final version of the game was developed implementing an iterative design-based research approach where we consulted with expert educational practitioners and incorporated their feedback over several development circles which led to significant changes and adaptations of the original (design) ideas for the game. In the next step of the development process, we aim at testing the game's usability before evaluating its educational effectiveness in a controlled intervention study from which we expect a facilitating effect on children's basic numerical skills. We consider the further development of the game an ongoing process during which we may keep adapting and optimising game elements to maximise its user experience as well as educational effectiveness according to incoming feedback and empirical evidence.

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Evaluating the Efficacy of a Serious Game in Enhancing Word Reading Speed

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Abstract: Dyslexia is a Specific Learning Disorder (SLD) characterized by subpar reading abilities in terms of accuracy and/or speed. Dyslexia can have a lifelong negative impact on academic and day-to-day life. However, early identification and subsequent training can help dyslexic children overcome their reading difficulties. For instance, tachistoscopic reading, a technique that involves presenting words for a brief period, has been shown to improve reading speed. Technological tools, such as serious games, can also be useful, and governments encourage their use to enhance the management of SLDs. In this study, we investigated the efficacy of a serious game called Tachistoscopio in improving reading speed in children. The game began with a short calibration process, followed by the presentation of a word for a brief duration. The user was then asked to write the word. We tested it on children, carrying out the pictorial system usability scale to assess usability and investigating the effect of class and gender through Mann-Whitney U tests. We determined it had excellent usability and could effectively adapt to users' abilities, as third graders performed significantly better than second graders ($p<0.001$). Following the success of this preliminary phase, 36 second-grade children, split into two groups, participated in a training study: 18 children underwent a three-week training phase with the game, while the remaining 18 children served as the control group. Before the training, we assessed all children's reading abilities using standardized word reading and vocabulary tests. The training involved four 20-item sessions per week. We then collected the reading performance of both groups again and used Mann-Whitney and interval estimates to test for statistically significant difference between the reading speed increments in the two groups. Their confidence intervals did not overlap (training: [0.11; 0.33], control: [-0.10; 0.05]), which suggests a significant difference between them. These findings suggest that Tachistoscopio may be an effective intervention tool for improving reading speed in dyslexic children.

Keywords: Serious game, Dyslexia, Learning, Reading speed, Videogame

1. Introduction

Literacy is a social determinant of health: people with low literacy skills are up to three times more likely to experience poor health outcomes, ranging from having less health knowledge, lower general health, and shorter life spans (DeWalt *et al.*, 2004). Nonetheless the efforts to provide adequate education to children, 5% to 20% of children cannot reach their peers' reading level (Wagner *et al.*, 2020), thus being affected by developmental dyslexia (Snowling, Hulme and Nation, 2020). Dyslexia is characterized either by slowness in reading or by several errors, globally making text reading and comprehension very demanding. Its diagnosis is usually belated after reading is supposed to be mastered (end of 2nd grade), hence a pre-clinical intervention – starting from schools – could be fundamental to start helping these children to improve in such a fundamental task.

Among different remediation attempts, it was reported that tachistoscopic reading helps improving reading speed (Lorusso *et al.*, 2005). Tachistoscopic reading is a technique in which a word is shown for a very brief amount of time, and the subject is asked to repeat it after it has disappeared. It promotes the global visuo-lexical reading, as the brief presentation time forces words to be read as a unit, instead of decomposing them into phonological sub-units, as it happens in character-by-character reading.

The stimulus presentation time is an important parameter to be tuned. If it is too long, it is useless; if it is too short, it is frustrating; if it does not vary according to readers' performance, they do not improve. Relevant differences between letters presentation time may be small, hence requiring the support of a technological device. This point is also highly recommended by guidelines on the screening and characterization of specific learning disabilities in general, and on dyslexia in particular (Associazione Italiana di Psicologia *et al.*, 2021), as

traditional paper-based assessment cannot provide sufficient information about the reasons for reading problems.

Moreover, considering the young age of its potential users, engagement is also a key element for effectively proposing this tool. Therefore, a suitable solution would be to implement the tachistoscope reading a serious game. In the past, a webapp was proposed to allow a remote assessment (Lorusso and Fumagalli, 2020). Even if webapps seem to make games widely available, in the case of training for reading difficulty their flexibility turns into a drawback: as it is not possible to control an important parameter, that is, words dimension, the game cannot be played on screens smaller than laptops, such as tablets. Instead, computers should be discouraged when performing this activity, as they cannot be compared to paper when used for learning (whilst tablet can) (Sage, Krebs and Grove, 2019) and, on the contrary, they cause more visual fatigue (Lee, Chiang and Hsiao, 2021). Moreover, data fruition is neither straightforward, nor targeted to teachers, as in the case of school-based training.

In the context of the ESSENCE H2020 project (www.essence2020.eu), several serious games to enhance reading, writing and calculation abilities were implemented, together with a narrative framework aimed at boosting engagement without affecting the "serious" purpose of the games (Piazzalunga, Donati and Ferrante, 2023). One of these games is the Tachistoscopio. The theoretical added value of such games is the possibility of gathering data on children's activity and to provide informative feedback to teachers, that could include them in a school-based training program. According to the training results, they can decide whether a clinical visit should be envisaged. To demonstrate the validity of the game in training children reading abilities, a validation process should be carried out. In particular, it should be confirmed that the game is capable of modelling children's abilities, it is perceived as useful and engaging by children, and it is effective in training them at school. Indeed, given the pre-clinical purpose of the game, one must investigate whether effective results could be achieved in short time spans, as an excessive number of game administration (e.g., 45 minutes, twice a week, for four months (Lorusso *et al.*, 2005)) would make school-level adoption not feasible.

Given these premises, this work has three aims: (1) to assess whether the Tachistoscopio game is sensitive to children writing abilities; (2) to assess the usability of the game; (3) to assess short term training effectiveness.

2. Materials and Methods

To answer the aims of the work, the first step was to develop the Tachistoscopio game. Then, two testing phases were organized: first an early testing involved second and third graders, to understand if different reading proficiency was captured by the game (aim 1) and to understand if it was usable from their perspective (aim 2); then, a field testing was performed with second graders, that were trained with the Tachistoscopio for a three-week period, to understand if any effect was evident with respect to a control group (aim 3). Subjects were recruited in the framework of the ESSENCE project, according to the protocol approved by Politecnico di Milano's Ethical Committee (n. 04/2021 for early testing, n. 36/2022 for training), in primary schools in the province of Varese. To assure that a training effect could be observed, a minimum of 9 subjects needed to be recruited. The sample size was computed based on previous studies on similar protocols (He, Legge and Yu, 2013), that assessed statistically significant differences between pre- and post-reading training, by considering a 95% level of confidence. Given the longitudinal design of the study, this figure was doubled to account for potential dropouts.

Statistical analysis was carried out in Python 3.8 and in Matlab R2020b. For all statistical analyses, the significance level α was set to 0.05.

2.1 Gamification of the Tachistoscope

What differentiates serious games from the mere digitalization of tests is gamification, a set of techniques aimed at exploiting human competitiveness and ambition as strategies to make the user accomplish the task in a more enjoyable way (Bedwell *et al.*, 2012). However, when developing serious games to train learning abilities, one must be careful not to excessively alter the rationale and the mechanics, as this may lead to a loss of effectiveness. To preserve the efficacy of the training, gamification elements should be external to the core mechanics of the games. In the ESSENCE context, serious games incorporate a guide character, unique settings for each learning domain, a narrative framework, and a system of coin collection that rewards accurate execution of exercises. Tachistoscopio, the game described in this work, shares these key elements. The game's difficulty dynamically adjusts based on the child's performance, ensuring a constant sense of challenge that encourages the player to commit to the task. Moreover, it takes place in a forest, the designated setting for

reading games, and features Falchetto, the forest's guide character, who provides tutorials. Falchetto is shown in Figure 1.

In particular, the story behind Tachistoscopio is the following: Falchetto, which is responsible for the collection and safeguard of the letters in the game world, is worried because a messy anteater has gone into his nest and has caused them to flee. The player is thus required to read words before they disappear, “capturing” the fugitive letters. It is worthy to note that these characters appear in other ESSENCE games as well.

Figure 1: Falchetto, the reading domain's guide character

2.2 Game Design and Description

The game has been developed in Unity 2020.1.6f1 and built for Android on a Samsung S6 Lite. It is a gamified version of the tachistoscope, an instrument used to show a word for very brief intervals.

The game was developed through a co-design process (J.E. *et al.*, 2011), during which all relevant stakeholders were involved both to identify the functional specifications and the parameters regulating the appearance of the words, and to iteratively test and refine the game. The list of presented words was provided by clinicians, who selected them based on their use frequency, length and complexity.

The first part of the game is calibration. In this phase, a word appears on the screen and the player must push a button when they are done reading it. The time needed to read each character is then computed as the time needed to read the word divided by its length. This value constitutes the reading delay, i.e., the time that needs to elapse before a character is read, and will influence the rate with which words disappear, to modulate the difficulty of the game. This procedure is repeated 10 times, and the final reading delay is computed as the average of the 10 individual values.

After the calibration, the game scene is loaded. In this scene, a word appears on the screen and remains visible for an amount of time equal to the reading delay times the number of characters in the word. Regarding the word’s disappearance, the game mechanics vary slightly depending on the value of the reading speed: if it is under 3 syllables/second, the word is cancelled letter-by-letter, otherwise it disappears all at once. Some noise appears on the screen to avoid the imprinting of the afterimage of the word on the retina. The two different cases are shown in Figure 2a and Figure 2b.

Then, the player must write the word in a pop-up. If the typed word is correct, positive feedback appears. After three consecutive successful attempts, the reading delay is decreased by 6 ms/character, producing an increment in the speed of cancellation. Conversely, after three errors the reading delay is increased by 6 ms/character.

(a) (b)

Figure 2: (a) Letter-by-letter and (b) global cancellation of words

2.3 Early Testing

2.3.1 Protocol

The preliminary testing phase for the Tachistoscope game was designed to ensure that the game was not only suitable for children but could also effectively adapt to their abilities. The testing phase involved second and third graders who played the game in a 10-item session after the calibration phase. During this session, the game recorded the initial and final reading speed achieved by the children in syllables/second and their accuracy.

To gather more information about the children, they were asked to complete a characterization questionnaire. They were asked about their dominant hand, mother tongue, and familiarity and habits with tablets and video games.

Finally, the children were administered the Pictorial System Usability Scale (P-SUS) (Baumgartner *et al.*, 2019). This was done to assess their overall satisfaction with the game. Moreover, a custom questionnaire, investigating how easy, boring and fun the game was, has been administered to understand the level of appreciation. Answers to this questionnaire were encoded on a 5-point Likert scale.

2.3.2 Statistical analysis

Firstly, to determine if the data was normally distributed, the Lilliefors test was utilized. Following the normality test, the Mann Whitney U test was conducted to examine the impact of gender and grade on game variables.

2.4 Training

2.4.1 Protocol

Children were firstly administered a series of tests to assess their reading capabilities and phonological memory. These tests are the De.Co.Ne. for words reading [13].

To be eligible for the study, reading abilities should not be affected by potential cognitive impairment. Hence, exclusion criteria were: scored below the 25th percentile in the CPM Raven matrices test (Raven, Raven and Court, 1998; Belacchi *et al.*, 2008) or scored less than or equal to 6 in the vocabulary test of the WISC-IV test (Wechsler, 2003).

Children who met the inclusion criteria were randomly assigned to a train group or to a control group. Children assigned to the control group did not receive specific training. Children assigned to the train group underwent a training phase with the Tachistoscopio game. They played the game in 20-item sessions four days a week for three consecutive weeks. Each session was conducted under the guidance of a clinician, who ensured that the children understood the rules of the game and were playing it correctly.

After the training period, both children groups repeated the reading tests.

2.4.2 Statistical analysis

Firstly, the Lilliefors test was used to check whether data about the reading speeds, both pre- and post-training, achieved in the word reading tests were normally distributed. Then, the increment in word reading speed was computed as the difference between the reading speed measured in the second time point and the initial reading speed, and t-test for normally distributed data or a Mann-Whitney test for non-normal data was performed to investigate if there were any differences between the trained group and the control group.

In case of uncertainty, confidence intervals were computed as follows:

$$CI = \bar{x} \pm z\frac{s}{\sqrt{n}}$$

where $\bar{x}$ is the sample mean, z is the confidence level value, s is the sample standard deviation, and n is the sample size. In the case the variable is not normally distributed, the sample mean was replaced by the median and the standard deviation by the inter-quartile range. To obtain a confidence interval of 95%, which corresponds to the chosen significance level α = 0.05, z was set to 1.96. If confidence intervals of the two samples do not overlap, it suggests that there is a statistically significant difference between the two populations (Cumming, 2013).

To check whether the performance of children who played with the Tachistoscopio increased over time, a Spearman's rank correlation coefficient test was performed on the time needed to read a character, which should be decreasing as the performance increases. The Spearman's rank correlation coefficient test can verify whether there is a monotonic relationship between two variables, in this case, time and milliseconds per character.

3. Results

3.1 Early Testing

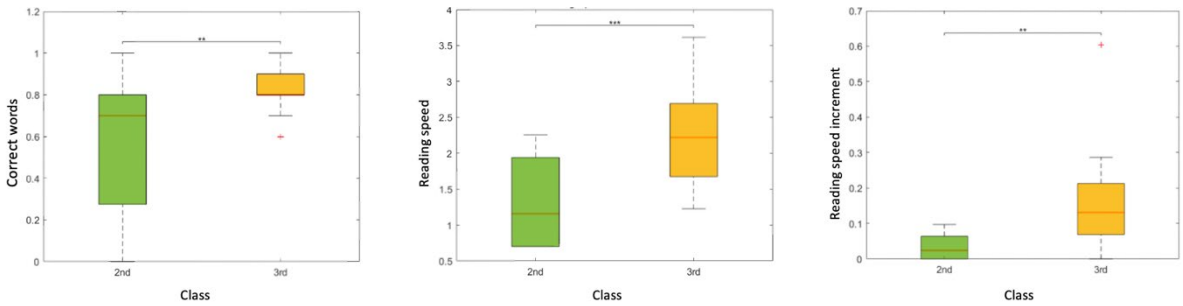
3.1.1 Sample

28 children participated in the study: 13 (7 females, 6 males) attended second grade, while 15 (8 females, 7 males) attended third grade.

3.1.2 Statistical analysis

Variables were not normally distributed, so the Mann-Whitney U test was used.

The results of the Mann-Whitney U test show a significant difference between the accuracy reached by second and third graders (p=0.005), with older children achieving better performances. The same trend is observed in reading speed, which is significantly lower in second graders than in third graders (second grade: 1.30±0.62 syllables/second, third grade: 2.24±0.67 syllables/second, p<0.001). There was no significant difference between males and females, neither in accuracy (p=0.740) nor in reading speed (p=0.052). Finally, the increment in reading speed at the beginning and at the end of the game is statistically different between grades as well (p=0.003), but not between genders (p=0.079). Boxplots for the three variables are shown in Figure 3a, 3b and 3c.



(a) (b) (c)

Figure 3: (a) Boxplot of the accuracy in second and third grade, (b) boxplot of the reading speed in second and third grade, (c) boxplot of the reading speed increment in second and third grade

3.1.3 Usability and appreciation

The SUS score obtained by the game was 86.2±14.4, which is considered an excellent usability score, as the minimum value to consider a tool usable is 68, and the excellence threshold is set at 85 ('Determining what individual SUS scores mean: adding an adjective rating scale', 2009). Regarding the appreciation, children were asked to express on a scale how easy (1 = very difficult, 5 = very easy), fun (1 = not fun at all, 5 = very fun), and boring (1 = not boring at all, 5 = very boring) they found the game. In Table 1, median values and lower and upper quartiles are reported for each question.

Table 1: Median scores and IQRs of appreciation questions.

	Median [Q1; Q3]
How easy was the game?	3 [3; 4]
How fun was the game?	5 [5; 5]
How boring was the game?	1 [1; 1]

3.2 Training

3.2.1 Sample

36 second-grade children participated in the study. 18 children were administered the Tachistoscopio training (9 females, 9 males), while the remaining 18 composed the control group (12 females, 8 males).

3.2.2 Statistical analysis

According to the Lilliefors test, the word reading speed variable did not result to be normally distributed. Therefore, the Mann-Whitney U test was carried out to compare the performance of the trained and control groups (independent variable) in the De.Co.Ne. test, separately for the initial word reading speed (before training, dependent variable) and the final word reading speed (after training, dependent variable). None of these two dependent variables were statistically different between the trained group and the control group. In Table 2, we report their median values, along with their lower and upper quartiles and the p-value of the Mann-Whitney U test.

Table 2: Median values and IQRs of reading speeds and reading speed increment, with the p-values of the Mann-Whitney U test performed between trained and control groups.

	Median [Q1; Q3] trained group	Median [Q1; Q3] control group	p-value
Initial word reading speed (syllables/second)	2.03 [1.53; 2.35]	2.06 [1.53; 2.41]	0.612
Final word reading speed (syllables/second)	1.95 [1.66; 2.64]	1.85 [1.75; 2.16]	0.788

The increment between initial and final word reading speed (dependent variable) was normally distributed, and thus compared through a t-test between the trained and control groups (independent variable), with a result of $t(36) = 1.84$, $p=0.074$.

Considering that the speed increment was close to statistical significance, the variable was further studied by means of its confidence interval of the mean. It was found that the confidence interval of the mean speed increment was [0.11; 0.33] for the train group and [-0.10; 0.05] for the control group. As the confidence intervals did not overlap, the trend suggested by the t-test was confirmed. It means that the reading speed increment is significantly higher in the trained group.

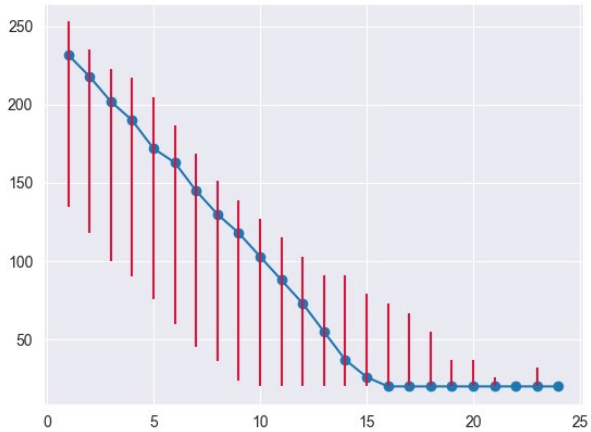


Figure 4: Plot of the median time needed to read a character during the whole training period. In red, the IQR of each measurement

To verify whether the performance in the Tachistoscopio game increased over time, we considered the mean time needed to read a character. Its trend can be observed in Figure 4. The number of sessions resulted to be significantly correlated to the time needed to read a character (milliseconds per character), with rho = -0.974, $p<0.001$, thus implying that the game produces a significant increase on the reading ability.

4. Discussion

In this work, a tablet app for training reading abilities was developed and preliminary validation was performed.

The co-design process was successful both in terms of appropriateness of game design and in terms of users' experience. As for game design, early testing results on second and third graders revealed that it is sensitive to different reading proficiency levels expected in two successive years of school education (aim 1). Specifically, third graders were significantly more accurate, faster, and improved more than their younger colleagues during game usage. Sensitivity to proficiency is a key element for the game to be effective, but longitudinal assessment to the same children is necessary to understand its efficacy in training. Hence, to promote repeated assessment, the second aim of the work was to understand if the game was usable. Usability was excellent, and the game was found fun and not boring at all. Both these results (appropriateness and usability) paved the way to the second phase of the study, i.e., the training phase.

Given these encouraging results, a training phase was organized to understand if a short-term training could improve reading abilities (aim 3). As the confidence interval of the mean increment of speed in the trained group and in the control group did not overlap, a group effect was found. This means that the Tachistoscopio game was effective in improving reading speed in children, even if training lasted three weeks only. This is a time frame way shorter than the usual training time found in literature (Lorusso *et al.*, 2005), that makes the game even more suitable for a school-level adoption, as it allows an intervention without excessive burden on other activities. However, the result was not supported by statistical tests. Even if significance was not reached on this parameter, there is an evident trend that confirms an important role of the app in improving reading speed. Probably, a slightly longer training period or an increase in the sample size would have confirmed the trend also by leveraging classical statistics.

Given the promising results, the ESSENCE H2020 project (www.essence2020.eu) ended with a strong request from teachers to have the developed serious games deployed to continue performing reading training for children in need. This is an important achievement, as schools are the first place where learning difficulty should be addressed, before referring children to clinicians, as early identification and training of learning weaknesses assure better efficacy of the training (Kadar *et al.*, 2020). Moreover, objective data coming from the game on reading speed and speed increment after treatment are useful parameters to evaluate children and better characterize their weakness, as fostered by national guidelines on specific learning disabilities diagnosis (Associazione Italiana di Psicologia *et al.*, 2021), as could be smart pens for dysgraphia (Dui *et al.*, 2021), eye tracking for dyslexia (Piazzalunga *et al.*, 2023), and so on.

As future work, the same training could be performed on dyslexic children to understand their reaction to training, and if further refinements are necessary to adapt also to this population.

In conclusion, the co-design and validation of the Tachistoscopio serious game was successful and paves the way towards a school-based training of weak abilities.

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A Slave Obeys: Capital Violence and Illusory Agency in *BioShock*

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Abstract: The video game *BioShock*, developed by 2K Boston, depicts a world in which a laissez-faire capitalist named Andrew Ryan creates an underwater utopia called Rapture that is devoid of institutionalized oversight and entitles all of its citizens to their own production. Despite this exceptional aspiration, the game opens to a metropolis in disrepair; it showcases the broken endgame of the objectivist paradise it critiques (Yeates, 2015). Kevin Roozen suggests, in his paper "Writing is Linked to Identity," that finding ways to engage students in a way that promotes selfhood is the key to engaging them as a community (2016). The brand of selfhood with which modern students in western capitalistic societies are familiar is often leveraged via excessive competition, and this suggests *BioShock* has unique insight to offer as a pedagogical locus (Kasser and Lin, 2016). Analyzing the inter-class competition within Rapture that caused the state of dissonance between its utopian ideals and dystopian practice leads to insight into the game's take on Randian Objectivism and class inequality, an especially salient and relevant context to consider within the context of western economies replete with increasing levels of economic disparity and unrest ("Politics of Poverty", 2010). In this essay, I approach *BioShock* with a Marxist perspective, aiming to showcase the game's depictions of the social consequences for Rapture's proletariat and bourgeoisie as meaningful insight into real-world class warfare. An important distinction I propose the game makes is in its depictions of agency, violence, and capitalism as intrinsically interconnected—they cannot be separated and are dependent on one another, because the sociological ecosystem established by the game's narrative insists that each element is required; in so doing, my contention is that the game should be considered not only as a pop culture artifact, but as a legitimate piece of academic criticism in the vein of Marx's *Manifesto*. I conclude that, in the game's philosophical space, to be a successful capitalist, one requires agency without restriction, and the only way to exact that agency is through violence. Through its articulation of these concepts, *BioShock* functions as a useful vehicle in the search for accessible introductions to various economic, philosophical, and epistemological lessons.

Keywords: Video games, Bioshock, Violence, Capitalism, Agency

1. Background of Violence

In his work on violence in capitalism, philosopher Ricardo Gutierrez, a disciple of political theorist Slavoj Žižek, separates violence into subjective and objective categories. He notes the distinction as important because one propagates the other, stating that every "subjective violence" requires an "objective background;" he goes on to propose that this objective framing "contains a systemic and more perilous violence," one which "prolongs and generates the very subjective violence that we are fighting and responding against" (2014).

Subjective violence, which is apparent and signals human mediums, contrasts with the objective environment that exists behind the scenes, influencing its actors to perform specific dramas (Gutierrez 2014). Ergo, the settings in which violent agents apply their force, be it physical or figurative, is conducive to those same agents executing and perpetuating violence. In the Rapture colony of *BioShock*, the city itself represents an objectively violent backdrop in which horrifying, genetically-altered denizens called Splicers perpetrate violence. To better understand the objective surroundings in which the interconnected themes play out in *BioShock*, it is best to first identify and describe how the game uses its setting as an organic backdrop for necessary brutality. The game's philosophical playground is located within Capitalism, a space Wally Gordon, in *Medicine, Conflict and Survival*, claims necessarily "means violence" (1997). And, psychologically speaking, one of the game's primary deliverables is the act and sense of torture both the Splicers and the player must endure and employ, so the connection between their economic plight and the torturous inevitability of their mutually assured destruction is clear. As an underwater haven for the elite shrouded in secrecy, Rapture is a test case in a particular form of torture en masse: isolation.

Andrew Ryan, a flamboyant and idealistic businessman, created Rapture as a deliberately isolated city submerged beneath the Atlantic Ocean. Obsessed with abject agency and freedom, Ryan divorced himself and Rapture from civilized society in an effort to separate the wheat from the chaff, in the most extreme version of sensory deprivation. Over time, the physical isolation from society created conditions tantamount to a psychological experiment conducted in solitary confinement. Such circumstances are traumatic for their subjects. Akil and Lobel wrote about the effects confinement can have on prisoners' psyches, indicating that the imprisoned are afflicted with "varying degrees of psychological pain," such as "paranoia … hallucinations, irrational anger … and violent fantasies," among other symptoms. (2018).

The subjects of Rapture are emotionally unstable, and their environment incubates their self-preserving rage into full-blown anarchic cruelty. Of course, such isolation also imposed a hard-cap on resources for these irrationally primed denizens to share; all imports were finite, constrained by a surface-to-sea supply chain. While the city sourced power and resources from volcanic vents, there was ever-present want and need for surface goods (as advertised by fliers in the section of the city called Fort Frolic, which claimed to have on offer the "latest surface fashions!"). Following an arduous inception—Rapture was built over the course of several years, with the process of shipping unprecedented amounts of bulk materials to the ocean floor, levying an extraordinary cost of time and money—competition was required as a means to distribute an insufficient stockpile, however unevenly.

Competition, necessary when dealing with such resource scarcity, heavily influences psychology. Gilbert et al came to the conclusion that it can have a “dark side,” noting that “insecure social environments” can foster “hierarchical view[s]” within a population, leading to individuals “with a fear of rejection,” and eventually to an “increase[d] vulnerability to depression, anxiety and stress” (2009). Epstein and Harackiewicz’s study in *Personality and Social Psychology Bulletin* clarifies this effect, stating that competitive structures can “have both positive and negative effects depending on the personality characteristics of the competing individual” (1992). It is thus established that Rapture was a pressure cooker of isolation, competition, and mental instability. In order to accurately assess the full effects of such circumstances on its population, it becomes necessary, then, to evaluate the psychological profiles of the citizens trapped therein.

1.1 Foreground of Violence

Andrew Ryan had hand-picked Rapture's initial population, forming it out of the people he viewed to be the "best examples" of humanity. Dubbed by their pater as the "best and brightest," this exclusive lot had to compete over the aforementioned finite pool of resources. Ryan’s philosophy was such that he divided society into two demographics: “men” and “parasites.” The surface world, amidst all of its politicking and judiciality, was filled with the “parasites” who took from others what they had not earned themselves, and Ryan “fled” them. Thus, he selected for the “men” who would produce and not leech from their neighbor’s ingenuity. Such politics of exclusion are a consistent background for violence, regardless of Ryan’s intentions. Andrew Ryan explicitly hand-picked the “best and brightest” from society to live in Rapture, where their ambitions and creativity could be realized, unrestricted by the rules and regulations of government, law, religion, and morality. The “best and brightest,” for Ryan, included specific groups who could go unfettered by society in Rapture: “the artist” uncensored, “the scientist” unbound from “petty morality,” “the great” unburdened by “the small” (*BioShock*). More specifically, those recruited to Rapture were eyed for their belief in Ryan’s “Great Chain” philosophy of solely contending for one’s “own interest”: Ryan was an avowed devotee of the “Market” and its providence. His ideology is best described in Ayn Rand’s manifesto, *Atlas Shrugged*, as spoken by the protagonist John Galt:

> *“In proportion to the mental energy he spent, the man who creates a new invention receives but a small percentage of his value in terms of material payment . . . But the man who works as a janitor in the factory producing that invention, receives an enormous payment in proportion to the mental effort that his job requires of him” (2005).*

Ryan extolled the virtues of successful minds, venerating ideas and denigrating physical labor. He was an objectivist, through and through, prioritizing production just as Rand herself, who said “productive achievement” was the “noblest activity” (1992). Residents of Rapture were picked for having bought into this ideology, hooked on the incentives and believing in Ryan like a prophet (one such rube was Peach Wilkins, who fittingly describes in an audio diary found in the game both the initial allure and eventual disenchantment that was surely experientially typical for Rapture’s citizenry: “We all come down here, figured we'd all be part of Ryan's Great Chain. Turns out Ryan's chain is made of gold, and ours are the sort with the big iron ball around your ankle”). With this hierarchy of output in mind, Ryan shepherded a flock of the “brightest” sheep, and promised them greatness in Rapture.

1.1.1 Violent characters

Analysis of this recruited lot proves useful in sketching a trajectory of Rapture’s course from its concept to its demise; they were the component parts, after all. The psychological profile of these select few presented Ryan with a populace predisposed to certain personality traits. Ryan’s crème de la crème headed their froth in individual economic mugs: their personalities and success stories were formed in situations in which they were elite. However, in Rapture, they converged into a new echelon. Amongst other elites, a new pecking order must

be discerned: the market demands the best, and the best demands a relegation of the worst. Perhaps unsurprisingly, Rapture's conception did not plan for sustainability and laborers brought on for initial construction had no accommodations waiting for them once the building was complete. A district in the city called "Pauper's Drop" formed out of the temporary housing in which they settled, and this stretch of eyesore was mostly ignored by Ryan, his sensibilities obscured by idealism. Unchecked incentives, gains, and losses without a safety net are rarely a precursor to a healthy society.

The objective background that Ryan erected was suddenly populated by subjects eager to (re)situate themselves on its competitive topography, albeit precariously, as they were situated without any assurances of safety or stability. And, psychologically speaking, the "brightest" were not predisposed to playing nicely together (as Rand would have it, anyway). This is a group composed, after all, of a few specific profiles selected by Ryan: the "previously wealthy," the sort who, according to a study conducted by Leckelt et al, are often more likely to exhibit "narcissism" and a tendency toward "increased risk-taking," notably netting the "lowest possible score" for agreeableness based on the studies' parameters (2022); the artists, who, as Brenda Booker et al note, frequently tally scores that are higher "on the personality dimensions of neuroticism and psychoticism" (2014); and the scientists, who notably self-report heavily prioritizing objectivity (Mahoney, 1979). In sum, a selection of risky and disagreeable narcissists, neurotic psychopaths, and objectivists all converged in an isolated underwater arena to compete in a zero-sum game.

After being granted access to the isolated confines of Ryan's submerged utopia, the citizens of Rapture competed over resources in a race to own supply lines and establish monopolies. At each other's throats from the day the city opened, they necessarily grew increasingly isolated in their deep-sea tank of recycled air. As the situation devolved, deformity and death were spread everywhere, virtually ricocheting back and forth from the fictional space of the game to the player, eventually permeating all involved and seeping into the very steel of the city. The game developer, 2K Boston, uses every cue at its disposal to reflect the depravity to which the population of Rapture is reduced, as the incongruity between the American exceptionalism endemic to the city's architectural design and the destruction and devastation enacted by its citizens, including the player, bears out on the streets (Yeates, 2015).

And the player, too, is grounded on the Zizekian landscape of gamified survival described by Gutierrez. Julian Dibbell, in his book *Play Money*, dubs this concept "ludocapitalism," and both Jack and his controller are thrall to it (2006). Dibbell outlines how systems of economy conscript their consumers into "pointlessness" unless they can "contrive new meanings for [their] daily grind"; fittingly, in *BioShock*'s case, its conception obviously services the greater ludocapitalistic imperative of selling a game, but within its own narrative, it capitalizes on players' drive to "win" by baiting them into a violent grind for power. As Dibbell suggests, "the grind must sooner or later become a game," and players play their role as Jack perfectly, every time. Rapture ensures this compliance by reinforcing the Zizekian, objective background of violence.

Rapture is a space in which "luxury apartments are inhabited by corpses and a theatre is used as a torture chamber" (Yeates, 2015). This visual violence, undergirded by the auditory dissonance heard in the musicscape's overtures of 1920s big-band American exceptionalism, fosters an ideological disconnect evident in the chasm separating the trumpeting grandiosity of Rapture's ambience from the glum palpability of violent destruction evident in every scene (Gibbons, 2011). This periphery, the setting of Rapture, demonstrates Gutierrez's objective background of violence, which presupposes competitive force as the only engine for change or influence.

2. Capitalism's Capitol

Rapture is the objective setting in which all characters in *BioShock* mete out their individual brands of coercive strength, and there is a subtlety to the formation of this systemic violence. Andrew Ryan's credo, "A man chooses. A slave obeys," begs for agency, and his efforts to build his submarine capitol reflect his desire to prove that only true agents are worth the fruits of their labor. This is the ideal upon which the city was built: "with the sweat of your brow, Rapture can become your city as well" (2K Boston, 2009). Ryan believes that government and religion are restrictive forces that shackle the captains of industry who own the means of production –the bourgeoisie– and redistribute their earned gains to the mass of "parasites" and "looters" who form the proletariat (Clardy, 2012). Ryan's idealistic focus on capital gains leaves him blind to the extremes of his ethos, however.

Characterizing Rapture's analogous sister city in *Atlas Shrugged,* Dr. Alan Clardy states that "if admission to this utopia is selectively based on creative drive and talent, if not genius (as appears to be the case), it would seem

that people used to working with their hands for a living might be underrepresented here" (2012). Ryan envisions a Randian Objectivist's ideal space in which ambition and exertion are let loose and encouraged to run rampant. It is an obvious parallel to Galt's Gulch in *Atlas Shrugged,* and Andrew stands shoulder to shoulder with Ayn (Gibbons, 2011). In this Randian Nirvana, the only moral imperative is to capitalize upon ideation and iteration, and refuse to live "for the sake of another man" (Clardy, 2012). Providence is seized by the most exploitative and opportunistic industrialist. Similarly, Ryan's dreamscape insists upon autonomy, unscrupulously so, but enforces cutthroat competition that scarcely affords anything resembling choice to the majority of Rapture's citizenry. Additionally, it disregards the plight of the laborers who must build an ideal space that they will not be allowed to occupy. Thus, while the bourgeoisie vest in self-interest and ideate, they disregard the needs of workers who must create foundational infrastructure. This inherent divide propagates isolation and increasingly severe self-interest steeped in competitive drive. Every citizen in this objective setting is the endgame for herself, and none are to meet the needs or promote the well-being of someone else (Clardy, 2012). For everyone but those few fortunate enough to sit with Ryan at the head of Rapture's table, there is only one mechanism by which to compete: violence. And the best tool with which to exert violence is a marvelous underwater commodity called ADAM.

3. The Currency of Violence

ADAM is effectively the currency of Rapture. It is a genetic reconfiguration serum discovered by Dr. Brigid Tenenbaum, derived from sea slugs found on the ocean floor alongside the foundations of the city. ADAM can be used to alter the human body in innumerable ways: from manipulations pursuant to cosmetic perfection to distillation into "plasmids'' which can be used to weaponize bodily energy into electric discharge or incinerating heatwaves. This discovery is a capitalist's dream, affording limitless possibility for personal indulgence and capital gain. It almost goes without saying that this marvel of science comes with a degenerative cost, as Tenenbaum explains in her in-game audio diary: "[it] acts like a benign cancer, destroying native cells and replacing them with unstable stem versions." Consequently, it is habit forming, as users attempt to replenish their ravaged bodies with more ADAM. As a pure capitalist, Ryan is unphased by potential side effects, noting them in his office chronicle as "blindness, insanity, [and] death" but insists that "the market is patient, and we must be too." Importantly, and devastatingly, ADAM can be re-harvested from those who have used it (called "splicers''), and can be "grown" most efficiently by implanting a sea slug into the belly of a female child. This creates a cycle of self-destruction for consumers that can only be temporarily alleviated by obtaining more genetic manipulation, and as more of Rapture's occupants chase vanity and armament, they each become the closest source of a remedy for each other. An insatiable demand for a necessary product is created on a societal level, and where there is demand in a capitalistic society, there must be supply. Tenenbaum needed a financial backer to get her discovery off the ground. Enter the superlative capitalist and the ostensible posterchild of Ryan's fantasy: Frank Fontaine.

4. Atlas Shrugs

Fontaine, not Ryan, is the true mascot of Randian philosophy for 2K Boston. A businessman and grifter, he sees Tenenbaum's discovery not as an opportunity to heal or repair, but for profit and power. His only concern is profit, and he will not play by even the loose rules set forth by Ryan and Rand: "fair play and mutual respect" (Rose, 2015). If Objectivism is an economic experiment, Fontaine is the variable that its conductors somehow did not foresee (Clardy, 2012). He bankrolls mass production of ADAM and unleashes it upon the fragile, upstart economy of Rapture under his company, Fontaine Futuristics. In an effort to increase supply, he founds an orphanage for adolescent women and tasks Tenenbaum with discreetly morphing the stray girls into ADAM harvesters dubbed "Little Sisters," who are each protected by an armored behemoth called a "Big Daddy." Fontaine is initially not only accepted by Andrew Ryan, but also unequivocally endorsed. Ryan blindly views the eventual bringer of his demise as a champion of opportunity and a role model for all of his less successful subjects. Blinded by his capitalistic ideology, Ryan even seems to admire Fontaine and resent those who wish to see the upstart businessman curtailed in Rapture, noting to a local business owner that he should not complain about "market forces," explaining that he wouldn't "punish citizens for showing a little initiative;" rather, as any true Randian would advise, he tells the man to "offer a better product." Fontaine then takes on the persona of "Atlas"—a mocking nod from the game's writers to the titular titan bearing the globe in Rand's opus, *Atlas Shrugged* —a man of the people who galvanizes the proletariat to wrest control of the city from Ryan. As Frank Fontaine, he openly mocks Ryan and the citizens of Rapture: "You don't have to build a city to make people worship you. Just make the chumps believe they're worth a nickel." However, as Atlas, he can use the

commodity of labor for his own gain. As the class warfare begins, the only recourse for the average civilian seeking influence or agency is turning to ADAM, and thus Fontaine, in the guise of the everyman, Atlas.

Within this objectively violent framework, 2K Boston then uses Frank Fontaine as the terminal perpetrator of subjective violence and the wrench in the Randian machine. Every enraptured denizen made her way to the industrial paradise with the idea in mind that she could climb the capitalist ladder and break bread with the elite in the boardroom, with anything less being considered table scraps. This is evidenced in the journal of Rapture's resident botanist, Julie Langford: "the only thing worse than a hypocrite is an unemployed one." However, as Atlas and Ryan wage war over ADAM and authority, they quickly require all cosmopolites to fall into line: either in league with the founder of the city, or with its new revolutionary. Such binaries are required by the very ethos Ryan espouses, per the Randian edict for self-interest. Everyone who is with Ryan is a "hero," and everyone else is a "criminal." Thus, agency is sacrificed at the altar of consumerism: in order to make themselves useful in this escalating conflict, everyone in Rapture begins consuming ADAM, side effects be damned. Fontaine takes advantage of this state of affairs. He is the preeminent foil to both Ryan and Rand and is the extreme representation of their individualistic values. With no rules save for self-interested capitalism, the quintessential gamesman destroys the entire Objectivist superstructure. The fallout of this collapse tumbles upon the player, who must engage in the city as an outlander seeking escape.

4.1 An Agent Without Agency

Jack, the protagonist and player character, arrives via plane crash as an unwelcome invader. From the beginning, he only seeks escape, but in order to pursue this goal, he accepts the aid of a disembodied voice coming from a two-way radio named Atlas (2K Boston). Mutualism sees the two work together, and right from the start, agency is called into question. In order to survive in the nightmare realm that Rapture has become, the player must use ADAM in self-defense. This is framed as a choice, but survival is not optional. Taking aim at the best source of ADAM, Jack can choose to harvest Little Sisters for more ADAM, killing them in the process, or spare them for less (Gibbons, 2011). Dr. Lars Schmeink submits this as a true narrative choice, pointing out the requirement of ADAM by the player for fighting unending hordes of enemies necessitates gathering ADAM from Little Sisters; it is the act of either "harvesting" or sparing the Little Sisters that "determines the outcome of the game," and Schmeink suggests that, "In offering a game structure in which the ending is determined solely by the actions of the player, *BioShock* deviates on a technical level from the most other first-person shooters which prototypically pursue a rather linear plot" (2009).

However, one should consider these divergent outcomes more closely before filing them as evidence of agency. In the end, what determines which of two possible ending cutscenes the player sees is the number of Little Sisters who were harvested or spared throughout the playthrough. If a particularly power-hungry player consumes those innocent children, they'll be greeted with an ending that forecasts their violent escape from Rapture followed by destruction wrought on the surface world. On the other hand, if a beneficent player concludes the story having spared those poor little girls, the cutscene will begin with Jack on the verge of being killed by Fontaine, before being saved at the last moment by all the Little Sisters; as compensation for Jack's kindness, the player watches twenty-one children leap on top of Atlas, repeatedly plunging their ADAM-harvesting syringes into him until he falls to the floor. Upon Fontaine's incapacitation, the Little Sisters do not stop, their simmering resentment on display, as they ceaselessly stab his corpse with needles. While the epilogue goes on to depict these girls as a newfound family for Jack, it is telling that, whoever does the saving, violence is required: either Jack kills Atlas, or the Little Sisters do. Is this really much of a choice?

I contend that, as for every other desperate splicer rampaging across the alleys of Rapture, Jack only really has the illusion of choice. His only choice is violence. If he is to survive, he will need ADAM. Even if he spares a Little Sister by removing her slug, he must kill her protector Big Daddy. This is the selection that the "free market" has enforced upon all of its subjects, and the "free market" is only what its godlike producers determine it to be. These two monoliths, Ryan and Fontaine, the idealistic demagogue and the pragmatic carpetbagger, systematically remove all agency from everyone along their warpath, turning every person into a resource.

The chief resource for both deific mavens is human bodies. Most notable among them is Jack, who, through gameplay and dialogue, discovers he is Fontaine's genetic creation, derived from illegitimate affair Ryan enjoyed in secret, indoctrinated, and shipped to the surface world to be recalled for the purposes of subterfuge amongst the commercial competition quickly devolving into outright war. 2K Boston's least subtle critique of a capitalistic system is the brainwashed trigger phrase that compels Jack to do as he is bidden. As Fontaine blithely explains over the radio, Jack was "genetically conditioned to bark like a cocker spaniel when I said 'Would you kindly." The descent from utopia to dystopia accelerates as the player wreaks havoc through the city and furthers the

violence already being wrought by splicers competing for ADAM and the favor of Ryan or Fontaine. Unbeknownst to the player, Jack has become the pawn in a proxy war, and the game has forced "[them] to become participants in the causal processes responsible for producing dystopia" (Nyman, 2014). As Fontaine's ace in the hole, Jack is gradually moved closer and closer to Ryan, until a final confrontation is imminent. By this point, even Ryan, a champion of free will in the marketplace—of the providence of genius put to work—succumbs to desperate violence and forsakes his own, sacred autonomy. Pushed to the brink by Fontaine's ruthless business practices, Ryan eventually breaks, suggesting that any inclination to question the precepts that built Rapture are akin to "surrender": "To question is to surrender. I will not question." To question, to think critically, is to surrender. A violent end is inevitable, for agency has become a myth to all involved. Ryan, once an advocate of Fontaine's strategies, by this point has forcibly taken Fontaine Futuristics and "nationalized" it (effectively creating the first social service in Rapture); Ryan thus became an enforcer for the "parasites" he reviles, taking away Fontaine's agency in a violent business maneuver. Fontaine, of course, is merely the creation of the extreme capitalistic systems in place in Rapture, an inescapable conclusion in a system without safeguards. And, Jack, ever controlled by the player, could have only ever performed as he did.

4.1.1 And the World Falls

2K Boston's thesis lies in the dialogue of this confrontation. With Jack on his doorstep, Andrew Ryan reveals his hand: he knows of Jack's origins, he knows he's lost the battle and will soon lose his life, but he will not concede the ideological war. His final speech distills the game's primary critique to its core:

> *A man chooses; a slave obeys. You think you have memories: a farm, a family, an airplane, a crash, and then this place. Was there really a family? Did that airplane crash, or was it hijacked? Forced down by something less than a man, something bred to sleepwalk through life until activated by a simple phrase from their kindly master? Was a man sent to kill, or a slave? A man chooses; a slave obeys. Come in. Stop, would you kindly? Would you kindly? Powerful phrase. Familiar phrase? Stand, would you kindly? Run. Stop! Turn. A man chooses; a slave obeys. Kill! (2K Boston)*

Ryan commands his assailant to attack, effectively committing suicide. In his last desperate act, he attempts to claim agency amongst the debris of violence that has doomed his vision, directing that violence inward. He claims that a man is distinct for his choice, and chooses death; however, this choice is predicated on violence, and borne by a capitalistic system that coerced each of its subjects into escalating force until the only path to agency for anyone, including Ryan, was an act of submission to violence.

As the perpetrator of this violence, the player has no real choice. Jack—whether armed to the teeth with ADAM and plasmids or staggering forward unaided by genetic empowerment with nothing but the civility of guns and righteousness at this point—is compelled by inconspicuous factors, such as competing for the very oxygen he breathes in a closed-circuit system, and conspicuous brainwashing. The player wades through the violent compulsions of every splicer remaining in the city, each bent on interdependent notions of survival and one-upmanship and clamoring for a chance encounter with a Little Sister for harvesting. As the body count rises and Rapture falls deeper and deeper into ruin, its founder dead, the terminal encounter of the subaquatic venture fatefully ensues, with Jack attempting to seize his own willpower and battle back against Fontaine.

In the head of Fontaine rests the ideal world Ayn Rand envisioned taken to extremes. He represents unchecked opportunism, as he radios to Jack in the game's final act: "I'm gonna miss this place. Rapture was a candy store for a guy like me. Guys who thought they knew it all" (*BioShock*). It is revealed in this inexorable philosophy that neither Rand nor Ryan ground Galt's Gulch or Rapture in reality: they each forgot to factor in the violence. Unlike Rand and Ryan, however, Fontaine counted on it. He counted on the "endemic social conflict, predominantly among the leading social classes" characterized by Warnecke-Berger in *International Studies* (2020). Fontaine exposes the element of volatility that *BioShock* contends must be taken for granted: that selfishness borne of the competition required by capitalism functions as a religion that will consume everything and everyone it touches, and cannot be the fulcrum of a balanced system. He stacks the deck in his favor, cheats his free-market competition off the playing field, and uses disingenuous idealism to enthrall its believers. Fontaine's force upends the entire experiment that effectively created him. He is the imminent conclusion of unchecked Objectivism. Andrew Ryan created a system in which absolute self-interest wins, and Fontaine represents the epitome of self-interest. As a bourgeois businessman, he props up and controls the only means of survival, ADAM, thus removing all choice from Rapture's free-market. By then masquerading as a working-class revolutionary, he raises the consciousness of the proletariat to an awareness of their desperate state of inequality. He then instigates civil war and plays his ace: Jack, the genetic clone who mistakenly believes he

violently fights for his own self-interest, when, in fact, he only serves his bourgeois master's selfish desire for profit and power.

In the end, it is neither Rand nor Ryan who ultimately fail their misguided utopia. Rather, it is an inevitable avatar of distilled, cynical self-interest who privatizes survival and peddles death, pumping the means to make it like poison into the veins of the city. *BioShock*'s thesis, then, is not an indictment of Rand's ideals, but rather a thought experiment based in Zizekian philosophy posing a specific question: what is the conclusion to any narrative predicated on fundamental objectivism? The answer? Universal objectification predicated upon necessary, violent seizure. As the ante is upped, self-defense and competition require violence if one is to survive, let alone thrive, in a capitalistic system without regulation. Thus, Rapture was always doomed to fail—not in spite of its ideals but because of them.

This is why *BioShock*, despite being released in 2007, is still an overwhelmingly relevant artifact for study in philosophy, economics, business, or even literature classrooms. Within capitalistic societies, there are increases in economic inequality and structural violence (Smolski, 2021), decreases in social welfare ("Poverty", 2022), perceptions of democratic ineffectiveness (Chiru, 2022), and movement toward technocracy (Cena, 2023) that all bear an eerie resemblance to the sort of status quo Andrew Ryan might endorse. Given the evidence for inevitable violence these trends have yielded and further portend, could we kindly cast a critical eye over 2K Boston's Randian treatise?

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Confidence in Movement-Based Game Design Facilitation: Learning From a Novice Design Facilitator

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Abstract: Several movement-based and embodied design methods have been developed to supplement existing game design methods. Facilitating movement-based design methods is a practice that most game designers must master. Facilitation involves taking on several responsibilities and roles to ensure processes and activities follow the design project's principal values. For instance, the facilitator must possess design expertise and social awareness, be a direction setter and trust builder, facilitate stage engagement and mood, energise for commitment, and maintain a playful attitude. The many responsibilities and significant involvement will inevitably affect the facilitator, who enters an affective state facilitating the design activities. Through a phenomenological comparative analysis, this study explores how novice versus experienced facilitators perceive the emotion of confidence and its implications on the facilitation process. This analysis is based on a single case study of a two-day movement-based sports innovation camp for 80 K-12 high school students. Empirical data were generated using a combination of observations and interviews with seven of the involved facilitators: three experienced facilitators and four novice facilitators. Our research indicates that facilitation can be categorised into three stages focused on (1) Structure, (2) Process, and (3) Content. Reaching the Content stages requires a high bodily involvement closely linked to the facilitator's confidence level, which we partially interpret as determined by the courage to use one's body as a facilitation resource. Thus, the facilitation Process depends not only on the facilitator's level of expertise but also on confidence level and courage. Consequently, we recommend thorough preparation for each facilitation stage to support the facilitator's confidence. Structure: Outline a detailed playbook, organise the physical space and prepare necessary materials. Process: Prepare strategies for providing guidance and feedback. Content: Implement Movement-Modifiers and participate in warm-up activities.

Keywords: Movement-based design, Embodiment, Facilitation, Design expertise, Exergame, Education

1. Introduction

In the overlapping fields of game-based learning and Human-Computer Interaction, there is a growing interest in working with the body, entailing the use of movement in designing. Body and movement are seen as sources of creativity and acknowledged as a way for designers to engage in design challenges in pursuit of insights (Loke and Robertson, 2011; Reidsma et al, 2022; Segura, Vidal and Rostami, 2016). In exploring methods and outcomes of movement-centric design practices, the importance of facilitating the right mindset and way to act through the design activities has been highlighted as crucial elements (Reidsma et al, 2022; Elbæk et al, 2022).

Mosely, Markauskaite and Wrigley (2021) define design facilitation as "the act of drawing on and applying design processes and approaches to enable dialogue and ideas to emerge within participatory design contexts..." (p. 11). Drawing on Loke and Robertson (2011) and Segura et al (2016), the role of the facilitator of movement-based design methods may encourage a 'movement first' principle and the use of the participant's own body as a source of knowledge, inspiration, and judgement.

Facilitation is a practice that most game designers must master now and in the future (Reidsma et al, 2022; Dahl and Sharma, 2022). Thus, it is an educational subject for competency building. The literature acknowledges that developing design facilitation expertise involves a reflective practice (Mosely et al, 2021; Dahl and Svanæs, 2020). Self-awareness and awareness of one's role may be essential in developing reflective facilitators (Dahl and Sharma, 2022). Being a facilitator requires many responsibilities and involvement, which inevitably affect the facilitator, who enters an affective state when facilitating the design activities. Fuchs and Koch (2014) state how motion and emotions are intrinsically connected as one is *moved by movement* and *moved to move.* Emotions are felt from the inside and are often displayed in expression and behaviour. In the social sphere, emotions are characterised by various potential movements related to an actual or implicit other. As Johnson (2017) states, "those who facilitate design learning must steadfastly negotiate their own fears as they lead others into the disequilibrium, uncertainty and radical reframing that reliably occur when designing" (p. 129).

Reviewing the literature on facilitation, no research on the interconnection between movement experience and facilitator experience was found. Different studies explored the influence of design expertise on the quality of facilitation (Reidsma et al, 2022). The success of a design session is partly dependent upon the facilitator's guidance and feedback (Mosely et al, 2018; Slovak et al, 2017; Lee et al, 2014). However, a certain design expertise level is required so that the design thinking methods can be successfully taught and given feedback. We recognise that being a novice or experienced facilitator might affect the affective state and, subsequently, the facilitation process. In the traditional design thinking facilitation, Mosely, Wright and Wrigley (2018) interlink seven ways of operating in design practice: result-focus, convention-based, situation-based, strategy-based, experience-based, developing new schema, and redefining the field with the design expertise levels stated by Hubert Dreyfus (1992). They correspond with the seven 'levels of design expertise': 'Naïve', 'Novice', 'Advanced Beginner', 'Competent', 'Expert', 'Master' and 'Visionary'.

Reidsma et al (2022) propose facilitators to build a safe environment. Still, little research explores the effects when facilitators themselves experience low confidence in their facilitation competencies, such as including their body as a facilitation resource. Thus, we examine the relationship between facilitators' confidence levels and how this impacts the inclusion of their bodies to set the stage for a movement-centred design process. Informed by Fuchs and Kock (2014), this paper explores the interactions between the facilitator's affective state, the level of expertise in the view of the novice-expert continuum, and the facilitation context and how they affect the facilitators' approach to the facilitation process.

We investigate the embodied affectivity of the facilitators leading a two-day sports innovation camp Bright over Night Movement 2022. We describe the case and our comparative phenomenological analytic approach. Our analysis shows three stages of movement facilitation which facilitators may alternate between. The facilitation process depends on the facilitator's level of expertise and the confidence level in which courage is crucial for bodily involvement. We embed our discussions in both the existing literature and the context of our own experiences, leading to the development of essential guidelines for facilitators. Thorough preparation for each facilitation stage can support the facilitator's confidence level. Outlining a detailed playbook and preparing necessary materials and design tools, preparing extra Mood Setters and feedback strategies, implementing Movement-Modifiers, and participating in warm-up activities are some of our recommendations for facilitators who aim to enact all stages of facilitation.

2. Background

2.1 Facilitator Roles and Responsibilities

Design studies in Human-Computer Interaction specifically address a facilitator's involvement is limited. However, research explicitly focusing on facilitation acknowledge the facilitator as one of several influential 'forces' in the shaping of the design process (Dahl & Svanæs, 2020; Wróbel, Cash & Lomberg, 2020; Mosely et al., 2021). A facilitator must navigate several complex contexts, shoulder many roles and responsibilities, and manage various social dynamics between the facilitator and/or the participants. Facilitators who are not aware of the social dynamics can pose a threat to the democratic and empowering characteristics of a design process as the strongest party otherwise has the potential to take over (Dahl and Svanæs, 2020; Slovak, Frauenberger and Fitzpatrick, 2017). As such, the facilitator must pick up, identify, and work with all complexities that exist in all groups involved in the process, including themselves, participants and stakeholders. Hogan (2005) notes that facilitators should recognise that groups work in different ways, and the social context and dynamics of the group shape the way facilitators need to act to enable a group process that is both structured and flexible. How facilitation is enacted can significantly impact activities, participation, processes, and outcomes. At times, the facilitator should provide firm guidelines and clear rules; other times, they may need to respond with high energy, cajoling, offering and enthusiastically accepting ideas (Balfour 2016; Dahl and Sharma, 2022; Reidsma et al, 2022; Wróbel, Cash and Lomberg, 2020). Facilitation depends on the individual facilitator, as the facilitator does not only set the rules and constraints but is always there personally, carrying out the activity (Dahl and Svanæs, 2020; Mosely, Markauskaite and Wrigley, 2021).

Design methodology research outlines several key aspects of facilitation, including the ability to deal with the uncertainty associated with complexity, multi-disciplinary, and outcomes that are not – and are not supposed to be – foreseeable in the early phases. Design projects are about exploring unknown possibilities; thus, the design outcome cannot be predicted before the design process. Therefore, uncertainty is a fundamental element in design practice (Daalhuizen, Badke-Schaub and Batill, 2009; Cross, 1990; Liedtka and Ogilvie, 2011) and requires perceptive and observant facilitators who can guide and inspire the participants and set direction for the design activities (Dahl and Sharma, 2022). Consequently, facilitators must bear a leadership responsibility

(Reidsma et al, 2022). Moseley et al (2021) argue that leadership skills are central to facilitating and implementing emerging ideas into organisational practice.

Dahl and Sharma (2022) identify six facilitator role facets corresponding to a set of responsibilities and strategies that foster a productive design facilitation process being (1) Trust builder, (2) Enabler, (3) Inquirer, (4) Direction setter, (5) Value provider, and (6) Users´ advocate. However, these role facets do not necessarily pertain to movement-based design processes. Reidsma et al (2022) instead suggest four roles that facilitators can adopt and alter during a movement-based design process: (1) Game master and Instructor, (2) Coach and Mediator, (3) Role model, and (4) Initiator and Animator.

2.2 Facilitating Movement

Movement-based design methods place the body at the centre of design activities (Reidsma et al, 2022; Segura et al, 2016; Loke and Robertson, 2011). Loke and Robertson (2013) argue that focusing on the moving body necessitates rethinking existing design approaches. We argue that this must also include the facilitation process. Luck (2007) emphasises the importance of facilitating design dialogue in cognitive-based activities and argues how facilitation expertise is performed and revealed in conversation. In facilitating movement-centric contexts like HangXRT bodystorming, however, Segura et al (2016) emphasise the importance of encouraging idea explanation through physical enactment rather than simply describing it verbally. Reidsma et al (2022) describe different levels of facilitator involvement ranging from “inside, playing” to “outside, observing and controlling” in movement-centric design. Undertaking the role of Role Model and Animator requires the facilitator to step into the design activity more immersed. For instance, the Role Model is seen as an ‘undercover facilitator’ in which the facilitator engages in the group activity and plays it out to help others participate (Reidsma et al, 2022). The Animator role focuses on animating movement instead of instructing specific movement techniques. This role begins with full active involvement, with the facilitator immersing themselves in the activity (Börghall, 2019). Consequently, facilitating movement-based design activities adds complexity to the facilitation as the facilitator must put into play one’s own body. This requires additional resources from the facilitator, such as body awareness and experience in body movement, e.g., dance, acting or sports training (Reidsma et al, 2022). The need for a spectrum of competencies also diversifies what facilitators provide to the design process, resulting in facilitators approaching roles depending on their (movement) background and experience. Reidsma et al (2022) elaborate that a facilitator’s key role is to create a safe environment, as people may otherwise feel exposed or embarrassed when asked to include movement as a design resource. Other research concurs with this notion that not everyone feels sufficiently competent in their bodily abilities to provide meaningful contributions to the design activity (Segura et al, 2016; O’Shaughnessey and Ward, 2014). As such, the degree of confidence concerning bodily competence may hamper the open exchange of ideas that movement-based design methods should evoke. Based on this outline, two separate domains become apparent: (1) The facilitator as an individual, counting the body, senses and emotional perception, and (2) the context in which the facilitator is centred. Fuchs and Koch (2014) present the theory of Embodied Affectivity, which examines the emotional interplay between a subject and the environment and the interaction between bodily resonance and body feedback, which occur as an internal process within the subject. The theory provides a suitable framework for our analysis when examining the properties that exist between the facilitator and the environment.

1.3 Embodied Affectivity

The theory of Embodied Affectivity explains the complex relationship between emotions, senses, and the body concerning different environmental or situational contexts (Fuchs and Koch, 2014). The theory’s first aspect occurs between the subject and the environment. According to Fuchs and Koch (2014), emotions are not exclusively internal phenomena confined to the psyche or the brain. Instead, the environment can have affect-like affordance qualities that impose impressions on the subject. Likewise, these impressions may spark certain actions concerning the body. Gibson (1979) explains how the environment can invite certain action possibilities; for example, a playground environment invites individuals to use their bodies for play. As such, an emotional feedback cycle exists between the subject and the environment, referred to as *affectivity* (Fuchs and Koch, 2014).

Embodied Affectivity states that part of the emotional perception is created as an internal process between the concepts of *bodily resonance* and *body feedback*. Research indicates that certain bodily resonance will impact the emotions perceived by the subject (Cuddy et al, 2012). Riskind (1984) found that participants who sat in a slumped position would remember more negative life events than participants who sat upright. This exemplifies that certain body utilisations will, in turn, affect perceived emotions.

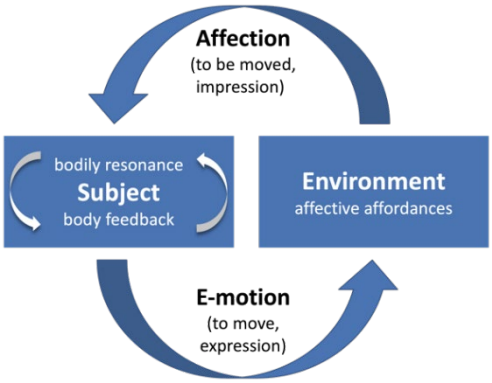

Figure 1: Embodied Affectivity theory from Fuchs and Koch (2014)

For our study, the theory of Embodied Affectivity provides a framework for analysing why some facilitators exhibited different levels of confidence in using their bodies as resources compared to other facilitators.

3. Case and Methods

An explorative qualitative approach was chosen, and a single-case study was adopted. In accordance with Stake (1995), we aimed to develop a comprehensive and context-dependent understanding of the embodied affectivity of being a facilitator of movement-based design methods. Drawing from the work of Allen-Collinson (2009), our work adopts a phenomenological approach, providing both theoretical and methodological insights into the lived experiences of the facilitators.

1.1 Bright Over Night Movement 2022

Bright over Night Movement (BoNM) is a collaboration between a Danish high school, the municipality of the high school, and the local university. The high school aims to incorporate design thinking in Physical Education (PE), and the municipality brings authentic cases for the students to generate solutions during a two-day movement-based sports innovation camp.

This year's cases focused on designing a 20-minute activity for 1) children in kindergarten, 2) eighth-grade middle school students, and 3) seniors in an activity centre. Three classes, 80 K-12 students, were participating and designed for one of the cases. 10 facilitators planned and facilitated the design process: Four master students from the local university and six PE teachers. As sketched out in the playbook, Table 1, the design model of Liedtka and Ogilvie (2011), with four guiding questions, What Is, What If, What Wows, and What Works, provided the framework for the design process, and movement-based design methods from the MeCaMInD card selection were utilised (cf. Elbæk et al, 2023b). The high school students worked in teams of 4-5 members.

3.1 Data Generation

Thorpe and Olive (2016) argue how observations of the activity in focus may serve as empirical data for understanding the context and identifying key themes. During BoNM22, observations were conducted to record facilitator behaviour, understand the context, and identify key themes in the facilitation process. Written consent to conduct observations and use the information in this study was collected from all participants and facilitators.

Table 2: A summary of the facilitators' gender, age, occupation, and level of design facilitation expertise.

Informant	Gender	Age	Occupation	Facilitation/teaching expertise
Ida	Female	26	MS, Sports and Health	Novice
Sigrid	Female	26	MS, Sports and Health	Novice
Catherine	Female	31	Physiotherapist, MS, Sports and Health	Novice
Anna	Female	30	Nurse, MS, Sports and Health	Novice
Eva	Female	49	High school teacher, PE	Experienced
Alfred	Male	33	High school teacher, PE and social studies	Experienced
Henrik	Male	47	High school teacher, PE and mathematics	Experienced

Informed by phenomenology (Allen-Collinson, 2009) and a review of design facilitation, an observation guide was developed. Specific observation points related to the facilitation process (Context, Social Dynamics, Moderation, Enabling) and phenomenological focus points (the what, the how, sensory impressions, curiosity, epoché, and openness) were included. The observation guide was tested at a movement-based design workshop

with sports students from the local university's bachelor course, The Creative Acrobatic Body (Elbæk et al, 2022). Insights from using the observation guide were analysed, and the guide was modified accordingly. In accordance with Ravn (2021), this supported the observation guide's purpose as an iterative tool to adjust the intentionality, oscillating between detailed and broad views of overlapping but diverse aspects of facilitation. Seven of the ten facilitators volunteered to be interviewed within 1,5 weeks after BoNM22 (Table 2), serving to generate descriptions of the lived experiences from the facilitation process. An interview guide was created, drawing from the insights of a review of design facilitation literature and our observational data. The semi-structured interviews lasted 45-60 min and were carried out individually, except for one peer interview with Anna and Catherine.

Table 1: A condensed presentation of the Bright over Night Movement 2022 playbook.

Design stage	Activity	Purpose	Execusion	Facilitator Roles
Thursday 08.12.2022				
	Mood Setter *'Silly Walks'.*	To playfully prepare the body for physical activity.	The participants walk across the room in a silly manner.	Role Model Animator.
What Is	Persona Mind mapping. Design Criteria.	Generating insights from the exploratory research of the What Is stage and use those to create design criteria that can be used to evaluate the activites generated.	*Persona:* Create fictional characters exemplifying certain attributes. *Mind mapping:* Organise the collected data to let hidden patterns and implications emerge. Design Criteria: Synthesiese important insigts and patterns from What Is to a set of criteria .	Instructor Coach.
What If	Mood setter *'Don't do what I do'.* Movement-based design method *'Daily Movement'* *'Explore Movement'.*	Performing a large variety of different movements. Exploring movement possibilities and generate movement ideas for further work development.	*Don't do what I do:* One does a routine movement, another approaches and does a different movement. *Daily Movement:* Do everyday movements related to the context. Act out the movement in specific scenarios and repeat with variations such as speed, scale, direction etc. *Explore Movement:* Play with props inspired by Movement-Modifiers.	Role Model Animator.
What If	Concept development.	Assembling innovative movement elements into a coherent activity that can be tested.	Organise movement outputs into coherent themes, forming concrete movement activities.	Coach.
What If	Movement-based design method *'Mockups for Movement Design'*	Exploring and gaining experience and understanding of the prototype activity.	Build a mockup for the activity using the necessary materials and tangible objects and explore the potential of the actitivy.	Coach Role Model.
What Wows	Testing movement activity on peer students.	Identifying the make-or-break elements of the movement activity.	One group at the time. 2 min presentation + 20 min test of actitivty + 8 min feedback and discussion with peers.	Coach.
Friday 09.12.2022				
	Mood Setter *'Clap cross'.*	Icebreaker to engage with a partner.	Pairs must continuously switch to clap as quickly as possible.	Role Model Animator.
What If/ What Wows	Adjusting movement activity.	Implementing learning points from test session.	Improve identified problematic areas and keep elements that work well.	Game Master Coach.
What Works	Test activity on the target group.	Let the target group experience and try the activity at the target location (Kindergarten, Public school, Senior activity centre).	One group at a time. 2 min presentation + 20 min test of activity + 8 min feedback and discussion with target group.	Game Master.
What Works	Poster session.	Pitching solutions to local health experts, politicians, and municipality professionals.	Three rounds for each group doing 5 min pitch + 10 min discussion.	Game Master.

The facilitator was asked to focus his/her descriptions on their own experiences and answer the questions with as many concrete examples as possible. Based on Høffding and Martiny (2016), this performed the phenomenological reduction. We adopted the role of active listeners, letting the facilitators' experiences direct the interview.

3.2 Analysis

The interviews were recorded and then transcribed verbatim for accuracy. The empirical data from observations and interviews were coded according to the terms 'emic' and 'etic' in a heuristic and iterative process described by Ravn (2021). Emic accounts, as understood in our study, are rooted in the cultural or subcultural context of the facilitators (Ravn, 2021). We were aiming for indigenous themes and meanings of the facilitators to understand and analyse according to the facilitators' subjective descriptions, getting an 'inside' perspective of their affective state. For the emic coding, we conducted a meticulous 'line-by-line' reading as van Manen (1990) suggested and organised the notes into themes that emerged from the facilitators' experiences.

Subsequently, we focused on etic accounts: reflecting theoretical ideas and taking on an 'outsider' perspective (Ravn, 2021). Informed by Fuchs and Kock (2014), we categorised the data into themes about the facilitators' affections, emotions, and bodily expressions during facilitation, aiming to gain deeper insights into how and why these experiences occurred.

As informed by Boeije (2002), the analysis also involved a comparative element. We compared interviews within the same group (e.g. novice versus novice) and interviews from different groups (novice versus experienced). When analysing the data, we looked for commonalities and differences in the facilitators' behaviour, reasons, attitudes, perspectives, and affections.

We condensed the interview and observation data into quotes, creating coherent, meaningful citations.

4. Findings

Analysing the interviews revealed how the facilitators emphasised affective intentionality towards the facilitator role and responsibilities, as being a facilitator and doing well was essential to them. They described how they focused on meeting the participants' needs and ensuring all groups delivered a valuable activity for the target group. When describing their roles and responsibilities, the experienced facilitators appeared notably objective, focusing strongly on the facilitation tasks and working towards solving the given case. Contrary, the novice facilitators were highly focused on the expectations associated with being a facilitator and the aim to do well. The experienced variances in the environment's affective affordance resulted in different emotional reactions. As an experienced facilitator, we observed Henrik as very confident. He explained, "I facilitated more than half the camp, so I feel confident facilitating the entire camp next time if necessary." In contrast, the novice facilitators appeared to be significantly impacted by feelings of pressure, high expectations, and low confidence. Catherine states: "I felt I was judged as some kind of "expert", but I did not feel like an expert at all".

Confidence level may be regarded as part of the facilitator's emotional response when assuming their role. Interestingly, the facilitation behaviour was based on the facilitator's affective state in the given situation, not only on the experience level. This we elaborate on below.

4.1 Handling Frustrations

As a design facilitator, you lead into the unknown. As Alfred states: "You must steer the process towards something – but you do not know what this 'something' is." Such uncertainty requires confidence for the facilitator to trust the process and planned activities and be prepared for the unexpected.

The facilitators described how they regularly experienced frustration among the participants and their need for help during the design process. At one point, a group decided to abandon their ideas, deeming them unworthy of presentation, which left them in a passive and emotional state. We observed novice facilitator Sigrid trying things like changing the location, asking questions, and encouraging the "yes-and" principle. However, as this did not work as intended, she described, during the interview, how her confidence level dropped, leading her to an affective state of frustration: "I did not know what to do. Some of me wanted to take control, telling them which idea to use, but I knew that was the wrong thing to do as a facilitator." Ultimately, she asked Alfred, an experienced facilitator, to take over.

As such, the facilitator's emotions imply embodied action tendencies, moving away from or towards the frustrated participants. When Sigrid starts to doubt herself, she steps away from the situation, removing herself from the unpleasant feelings.

4.2 Courage to Challenge Bodily Involvement

Facilitating movement-based design activities inherently places the body at the forefront of the design process. However, during the observations, we saw a clear difference in how the facilitators engaged their bodies.

Interestingly, this was not dependent on the facilitator's level of expertise. Instead, all facilitators emphasised courage as a critical factor for how to use the body. Ida and Anna limited their bodily involvement to supporting communication through gestures. Contrary, the other facilitators (both novices and experienced) engaged their bodies more, playing along during the activities and undertaking the roles of Role Model and Animator to challenge and support creativity. Anna and Catherine elaborate:

> *Anna: "It [involving one's body] requires that you, as a facilitator, are not scared, that you dare to use your body and act out. Just like the participants."*
>
> *Catherine: "Well, I do not have a problem looking and acting silly, so if I struggled to get the participants to crawl, I just started to crawl around on the floor to let them know that was the meaning of the Modifier..."*
>
> *Anna: "Yes. But I think it is very difficult for me if I am the only one looking silly. Then I fear looking silly, and I do not go there."*

5. Discussion

5.1 Stages of Movement Facilitation

Based on our findings, we suggest three stages of movement facilitation (Figure 2). The first stage of facilitation focuses on the structure of the design process, planning and instructing the design activities. In the second stage, the facilitator also focuses on the process and how to keep the participants engaged. In the third stage, the facilitator is focused on the content, trying to challenge and tweak the participants' ideas. Each stage requires different levels of bodily involvement. Focusing on structure, the facilitator mainly stands 'outside' and controls the design process and activities. Informed by Reidsma et al (2022), this stage's facilitation behaviour is closely related to the role of the Game Master and Instructor. The Game Master plans and prepares the activities and oversees the design process, whereas the Instructor focuses on starting, explaining, and executing each activity. In both roles, the facilitator adopts a third-person perspective, orchestrating the process from the outside, observing, and letting the participants do the playing (Reidsma et al, 2022). However, facilitating at the process stage requires a more profound level of bodily involvement from the facilitator. This stage implies close engagement with the participants, such as playing along in the design activity, responding energetically, or facilitating group discussions. The process-focused stage can be closely related to the role of the Coach and Role Model (Reidsma et al, 2022).

Deeper bodily engagement is required in the content-focused facilitation stage. In this stage, the facilitator must play along in the design activity to encourage and support movement inquiry and ideas, helping the participants to improve performance and achieve a valuable design outcome. This behaviour is closely related to the Animator in which the facilitator mainly takes on 1st- and 2nd-person perspectives, starting from full active involvement and losing themselves in the activity (Reidsma et al, 2022; Börghall, 2019). Also, the Coach can be associated with this stage as the Coach helps people identify interesting ideas that emerged and can use the body to "show by doing" to nudge and steer the group in better directions (Reidsma et al, 2022).

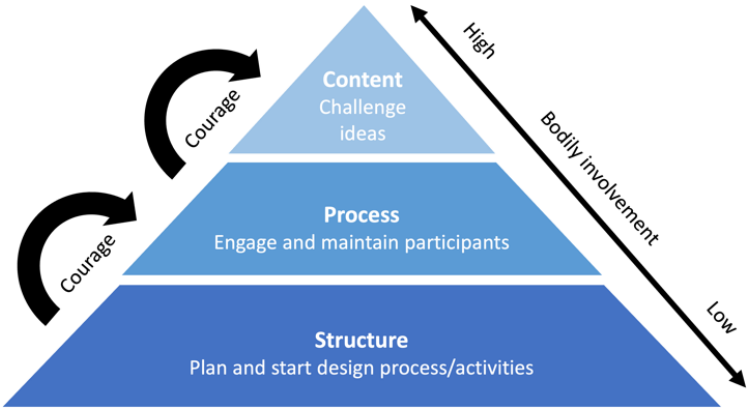

Figure 2: Illustration of the three stages of facilitation. Reaching the upper stages require a high bodily involvement which are closely linked to the facilitator's level of confident which is determined by the courage to use one's body as a facilitation ressource

Research into facilitation indicates that the level of an individual's design expertise impacts their application of specific strategies to problem situations (Mosely, Wright, and Wrigley, 2018; Luck, 2007). Our analysis indicates that the experience level influences which facilitation stage the facilitator finds themselves at. We also saw how the facilitator's emotions, like the level of confidence, highly affect the facilitator's behaviour and that courage is decisive for the facilitator's bodily involvement. Having the bravery to actively involve one's own body in the facilitation process – risking looking silly – does not inherently correspond to being an experienced facilitator. Novice facilitators Sigrid and Catherine had the courage to involve their bodies in the facilitation process. They used this as a resource for a higher bodily involvement stepping into the facilitation stages focused on the process and content, undertaking the roles of Coach, Role Model, and Animator. As such, understanding the facilitation process solely by focusing on facilitation expertise expressed through facilitation strategies may be too narrow. Consequently, we should also focus on the internal and emotional aspects of the facilitator, as emotions are not only felt from the inside but also displayed in expression and behaviour (Fuchs and Kock, 2014), potentially hampering the facilitation process.

In a movement-based design context, the facilitator's confidence level may have an even more significant influence on the movement-based design activities and add a layer of complexity to the facilitation process. Facilitating movement-based design methods requires additional resources from the facilitator, such as body experience and awareness (Reidsma et al, 2022). For that reason, experienced designers of cognitive-based design methods may not be expected a facilitation behaviour with high bodily involvement, undertaking the role of, e.g. Animator, if they do not have a movement background or do not feel confident using their bodies. However, this warrants further investigation. As there is a growing interest entailing the use of movement as part of the design process (Loke and Robertson, 2011; Elbæk et al, 2022), these insights are essential for future generations of movement-based design facilitators since the way facilitation is enacted depends on the individual facilitator (Dahl and Svanæs, 2020; Mosely, Markauskaite and Wrigley, 2021). Having the courage to apply high bodily involvement, thereby being able to navigate all three stages of facilitation, provides the facilitator with more actions to choose from when guiding and supporting participants. Ultimately, this will significantly impact the activities, participation, processes and design outcome (Dahl and Sharma, 2022; Reidsma et al, 2022; Wróbel, Cash and Lomberg, 2020).

1.2 Limitations

Throughout this study, we focused on what we believed would provide the most novel insights from the facilitator's perspective. Therefore, we excluded participants of BoNM22 as a source of empirical data to focus on the often-overlooked aspect of the facilitator's confidence, courage, and impact on bodily involvement. Secondly, the setting of BoNM22 provides some contextual limitations, such as the number of days over which the data was collected (2) and the number of facilitators who participated in the design facilitation (10), out of which seven were interviewed. Given these constraints, we regard this study as a preliminary investigation which yielded significant, albeit restricted, insights. Consequently, further studies which span more significant periods involve more participants and compare results from different design facilitations are recommended.

5.2 Recommendations for Novice Facilitators

Our findings reveal the pivotal role the facilitator's level of bodily confidence plays when integrating the body in a design facilitation context. As such, seeking actions that may assist is advised before facilitation. We advocate for comprehensive preparation, which is crucial for fostering a reflective facilitation process (Dahl and Sharma, 2020; Mosely, Markauskaite, and Wrigley, 2021). Utilising our model of the three facilitation stages (Figure 2), future facilitators can prepare strategies for each stage, thus strengthening one's action possibilities and contributing to a successful session.

- Since Stage 1 emphasises the design process's structure and planning, the facilitator could benefit from, for example, drafting a comprehensive playbook, strategising on organising the physical space, preparing requisite materials, and design tools like design cards and artefacts (Mosely et al, 2021; Elbæk et al, 2023b).
- When preparing for Stage 2 and how to keep the participants engaged in the design process, the facilitator must prepare strategies for providing guidance and support to the participants. Preparing extra energisers, getting familiar with the chosen design methods, and encouragement and feedback strategies can be prepared by the facilitator in advance and serve as focus points for reflection (Reidsma et al, 2022; Slovak et al, 2017).
- Preparing how to challenge the content in Stage 3 may include the employment of Movement-Modifiers (Elbæk et al, 2023a), cultivating a movement mindset, and participating in warm-up

exercises, which can foster a safe and friendly environment (Reidsma et al, 2022) to support both participants and the facilitator.

- Considering inherent uncertainty, the facilitator is advised to prepare backup plans for each activity. Should the need arise, these must be utilised – a crucial part of the facilitator's responsibility.

6. Conclusion

The facilitation process is intricate, going well beyond performing strictly by the book due to inherent uncertainty within the design process. Facilitation of movement-first design sessions is often highly influenced by the facilitator's level of movement expertise as well as the facilitator's affective state, which environmental factors, such as the context of movement-based activities, can impact. Being the leader of the unknown, the facilitator must shoulder the responsibilities inherent in their role. Consequently, novice exergame design facilitators should focus on bolstering their confidence, mustering the courage to choose among Structure, Process, and Content stages, and utilising their bodies as resources. This strategic approach will enable the emergence of movement dialogue and ideas within participatory design contexts and potentially transform how we approach, understand, and innovate the facilitation of movement-based design.

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A Video Game to Teach Young Adults the Brain Basics of Addiction

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Abstract: While we struggle to find effective ways to prevent drug-related harm in young people all around the world, families and communities continue to get hurt. World-renowned experts on addiction believe if people understand its basics, they will make better decisions regarding drug use. Nonetheless, addiction happens in the brain, and the bases of brain function involved in addiction are quite complex. I asked whether young adults could learn with a video game some important basics of synaptic function in the brain related to addiction. My team and I developed 'You VS Drugs', a 3D video game beta which, through an adventure that takes place inside a synapse between two cells, explains some of the complex bases of brain function different drugs alter to produce their effects, including addiction. I ran an online questionnaire in which, as 340 young adults aged 18-25 viewed the video game content, answered five multiple-choice and two true-false questions which sought to measure their learning. Then, we ran a simulation with a thousand hypothetical participants who would answer the questionnaire at random. We found that, on average, participants had significantly greater performance on the questionnaire than the simulation group (p <.00001, r = .77). Also, the average of correct responses participants gave over the course of the video game (5.644) corresponds to a group performance of 80.63% in the questionnaire. Results show young adults understand complex bases of neurobiological function related to the effect of psychoactive substances and addiction while playing 'You VS Drugs', and they also highlight the potential video games have to teach complex subjects in an engaging way. If we want to reduce the misery drug addiction imposes on families in our societies, we should educate young people in any effective way possible.

Keywords: Addiction, Drugs, Brain, Education, Prevention, Video game

1. Introduction

Substance abuse remains a dire, persistent and pressing problem for many young adults (Lipari *et al.*, 2013), and the effects of this disorder not only impact them, but also their family and community (Lander, Howsare and Byrne, 2013). We also struggle to find effective ways to respond to problematic substance use in young people. Startling evidence comes from a review of systematic reviews that analyze the efficacy of various approaches to prevent, preemptively intervene, reduce harm and treat problematic substance use in youth (Stockings *et al.*, 2016). By classifying the treatments for dependence or substance use problems by effect, level of evidence and size of effect at three levels ('use', 'problematic use', and 'injury or harm´), the authors disentangle how approaches to intervene drug use differ according to age, level of substance use and socioenvironmental context. Unfortunately, the results are daunting: the review shows some effective measures to reduce alcohol and tobacco use are not available to target illicit drugs, and reveals the ineffectiveness of (a) social norms, (b) brief interventions to reduce substance use, and (c) prevention interventions which give information about substance use, the effects, and health risks. Also, there is little evidence of published work to prevent drug-related harm (Boden and Day, 2023).

However, after analyzing data for decades, scientists at the U.S. National Institute on Drug Abuse believe, "increased understanding of the basics of addiction will empower people to make informed choices in their own lives…" (NIDA, 2023). Although that statement seems a light in the darkness, it remains elusive how to implement such educational and preventive strategies so young people understand the basics of addiction since many of those fundamentals happen inside the brain in quite complex ways, and they are not only quite difficult to understand, but also take a long time to explain. So, how can we motivate a young audience which is not looking to actively study neuroscience to stay engaged long enough to master the fundamentals of addiction, and how different drugs have different effects on different parts of the brain? How can we explain all the relevant neurobiology in a simple way, so it becomes easier to understand?

To tackle these issues, since mid-2018 I have led a team which has been implementing an adventure saga inside the brain in the form of a video game, and we materialized a functional scenario during the Covid-19 pandemic. I then asked whether young adults could learn the basics of synaptic function with this first scenario. We are building a serious game saga that has peer-support at its core, where it hopes to be fun while building long-term engagement, mainly through intrinsic rewards (Staiano, 2014; Abdul Rahim and Thomas, 2017; Sardi, Idri and Fernández-Alemán, 2017). The novelty of our approach is to involve people within an adventure inside the brain: a story arc of friendship, loss and redemption. The objective was to measure whether the content of the video game was good enough to explain some neurobiological facts —particularly events which occur where cells communicate, called synapses— which psychoactive substances alter when they reach the brain.

2. Methods

Instruments and participants

The video game has a chibi cartoon-style, 3D graphic design of characters and settings, and it belongs to the action-adventure third-person genre for PC and mobile devices. It gives players a sense of fun at first glance. Friends and foes, level challenges, sounds, structures and objects are designed for players to explore, have fun, get surprised, fight and make decisions that test the players' knowledge (see Figure 1). The video game depicts the function of the working brain, mainly at the synaptic level, with educational and preventive intentions. As the story unfolds, the game introduces the function and possible fates of neurotransmitters between two cells. Although the detailed content of the events shown in the video game are beyond the scope of this article, the time comes when the player must use the provided information to answer seven questions mentioned in the evaluation block, described further below. According to the players' answers, the neurotransmitters take different paths which can lead them to continue with or without sustaining damage. Neurotransmitters can succeed in locating receptors, finding a way to activate them and return to their cell, wander around and/or face enzymes that can take away part of who they are and inactivate them.

Figure 1: Gameplay depiction of two acetylcholine neurotransmitters and the enzyme acetylcholinesterase in 'You VS Drugs'

Four hundred young adults volunteered to participate in the learning activity. Participants were recruited primarily through networks at different universities and degrees, and personal networks. Scientific literature suggests young adulthood spans ages 18 to 25, as it is when people develop psychological, cerebral and other biological ways which bridge the differences between adolescents and adults (Bonnie *et al.*, 2015; Higley, 2019). Although that range is somewhat strict and therefore leaves little room to represent variability within a population, I decided to invite people within that strict age range to remain consistent with data analysis across domains of research and policy (Bonnie *et al.*, 2015). Nonetheless, some people outside the age range showed up at the virtual learning sessions. To ensure data analysis within the proposed age range, the questionnaire asked participants to enter their age without any warning. For example, if someone outside the age range was curious about the topic, wanted to learn about it, or just wanted to see the video game, asking them to leave the session beforehand could make them lie about their age. At the same time, I had no reason to believe the results were going to differ significantly if I extended the age to encompass a wider range of individual variation, these people's data were excluded after they participated. In the end, only data from 340 participants aged 18-25 were analyzed.

The questionnaire was created using Google Docs forms. Although it was labeled 'Learning Activity: Psychoactive Substances' to make the game intention explicit, it was made clear no information about them was going to be presented. Solely they were going to see an audiovisual representation of basics of normal brain function that

are necessary to later understand how substances have different effects on the brain. The questionnaire consisted of three blocks: (i) disclaimers and instructions, (ii) general information and (iii) assessment.

In the first block, participants were reminded both in writing and reading the learning activity was not mandatory for them in any way. Since the sole objective was to see whether the content of the video game was appropriate to teach some basics of brain function to a young audience, the only thing they had to do was to pay attention to their screen at home, and when questions showed up, they had to answer them on the online form at that precise moment.

In the second block participants selected their age group and the socioeconomic stratum to which they belonged. The four age groups within the range of interest were 18-19, 20-21, 22-23, and 24-25. In Colombia there are six socioeconomic strata (Article 102, Law 142 of 1994), as follows: 1) low-low, 2) low, 3) medium-low, 4) medium, 5) medium-high, and 6) high.

The last block was devoted to measure the participants' responses related to seven introductory aspects of chemical communication between cells, such as a brain cell and a muscular cell. The content of the questions was related to: (1) the purpose of neurotransmitters, (2) how they produce their effect and where, (3) whether their goal/purpose is at risk if they meet others alike, or different ones, (4) what can happen when they reach the next cell, (5) the significance of *affinity* and (6) *activity* between neurotransmitters and a receptor, and (7) the main reasons neurotransmitters may fail to return to the cell they came from. Of the seven questions, five were multiple-choice single answer, and the two related to affinity and activity were true or false.

Steps were taken so that the questions discriminated who was really paying attention and learning, and who was just looking at the screen without paying much attention. As a general rule, relevant concepts mentioned once, but not evident in the non-linguistic audiovisual content, were evaluated. However, two exceptions seemed necessary: as questions (4) and (7) related to crucial aspects of synaptic function, they were depicted through non-linguistic audiovisual content, and were evaluated near the end of the game. Finally, wrong answers in the multiple-choice questions were semantically related to the game story, so the correct answers were not too obvious.

Procedure

Due to the Covid 19 pandemic, the learning activity was carried out through virtual platforms and presented to groups of young people between March 18, 2021 and March 2, 2022. The transmission of the video game content lasted around 80 minutes on average. As the game unfolded and the questions appeared on the screen, the participants answered them in real time through Google Forms. They were given one minute to do so from when they showed up. Feedback on the right answers was never given to the participants until the activity was finished.

After obtaining the data from the participants, a simulation was run in which scores were obtained from a thousand hypothetical participants who would answer the questionnaire at random, as would be done by people who ignore the basics of brain function shown in the video game. The simulation considered the number of possible answers to the seven questions. It did not matter that the number of simulations was greater than the number of study participants: the more simulations, the probability of obtaining a result by chance is better represented. Also, by analyzing probabilities data become more generalizable.

3. Results

I found, on average, participants had significantly greater performance on the questionnaire (M = 5.644) than the simulation group (M = 2.579; $t(677.14) = -31.417$, $p < .00001$, $r = .77$; Figure 2). Also, the average of correct responses participants gave over the course of the video game (5.644) corresponds to a group performance of 80.63%, while the average of correct responses in the simulation group (2.579) equals a group performance of 36.84%. I found no performance differences between different age groups, nor between participants from different socioeconomic strata.

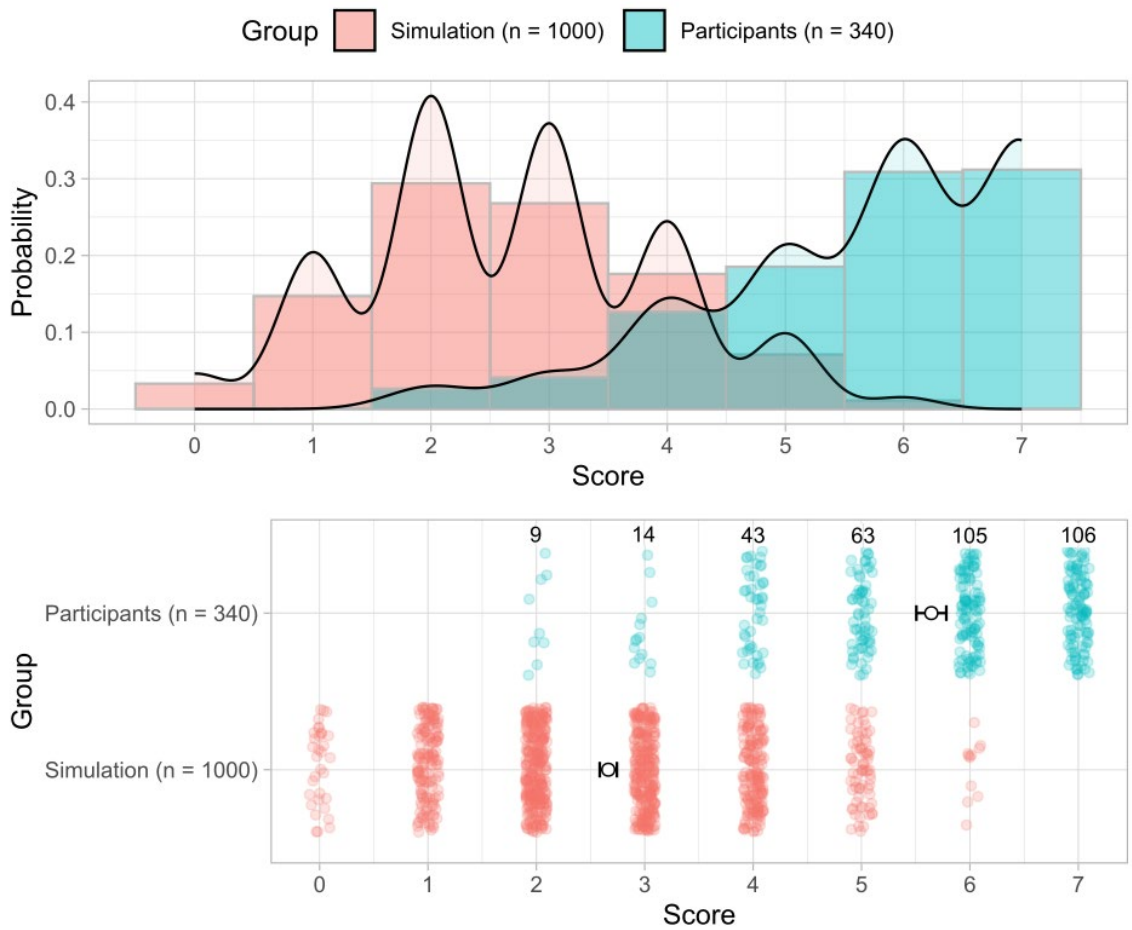

Figure 2: Above, solid lines represent the probability distribution of scores in each group, on top of the histogram with the score distribution. Below, the number of participants by score. The extent to which the scores of each group are significantly different can be appreciated. White dots represent the mean for each group and the 95% confidence intervals

4. Discussion

I found robust evidence young adults learn brain basics of synaptic function with the first scenario of the video game saga 'You VS Drugs'.

The findings are also novel because, to my knowledge, it is the first time the basics of brain function have been taught with a video game which shows the development of these events at the synaptic level. Furthermore, if it is true people will make better decisions in their own lives if they understand the basics of addiction, the results of this study are important for young people as substance use and its challenges are high among them (UNODC, 2018). I argue the features of 'You VS Drugs' are effective as learning tools.

A valid critique of the quantity and the way in which I selected the neurobiological aspects I evaluated can come from its objectivity/subjectivity. Why these seven aspects and not others, and why not more, or less? The way in which neuroscientists study the brain involves both different levels of its structure and mechanisms that generate changes in it (Figure 3). At the time of writing this article, I have already defined how to involve all thirteen levels and mechanisms in the video game saga, and eight of them are already implemented.

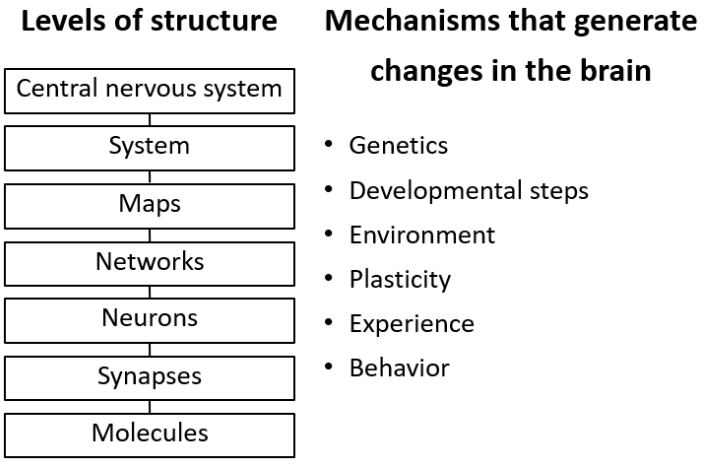

Figure 3: Different levels of brain structure and mechanisms. Taken from Wang (2010)

Now, the reasons by which I selected the aspects to evaluate are somewhat subjective is they are contingent on how explicit or implicit they become in the story one decides to tell. Mainly, the aspects in which one emphasizes should be the ones that are evaluated. However, in this case I decided to evaluate relevant concepts that are briefly mentioned but are not evident in the non-linguistic audiovisual content. Otherwise, I would be asking obvious concepts, and the questions would not fulfil the objective of discriminating who is really paying attention and learning, and who is only interested in playing. Another reason the aspects to evaluate were somewhat subjective was any story told depends on the one who tells it. In this case, after polishing a fictional story based on neurobiological events, I did my best to adapt it to the number of aspects I could evaluate without sacrificing the flow of the adventure. Of course, many more important neurobiological aspects that I did not evaluate emerge within the story arc both through language and audiovisual components, and I obviously welcome suggestions and critiques regarding the aspects I evaluated from anyone who plays the game.

It is also important to state details of the seven aspects measured may vary depending on the types of neurotransmitters and receptors, and there are other aspects which need to be shown before explaining the different effects of various substances in several parts of the brain. They will be explored in future updates of the video game saga. However, I decided to base the initial understanding of those aspects on the function of the neurotransmitter acetylcholine and its receptors due to (a) the story arc that I seek to tell throughout the whole saga; (b) that its action in muscles allowed me to give an introductory example of cellular communication before going into the neurobiological aspects of the brain, but at the same time (c) this neurotransmitter has a fundamental role in the brain's reward network, which is crucial for understanding the different ways in which different psychoactive substances have different effects in different brain structures, (d) promoting changes in active synapses, and (e) in how addiction can develop when using such substances (Grasing, 2016; Brzosko *et al.*, 2017; Galaj and Ranaldi, 2021). In addition, it is interesting the function of acetylcholine and its receptors constitute the basis of the story within the video game since they were also the first to be discovered by scientists, and therefore became the basis to study other types of neurotransmitters and receptors (López-Muñoz and Alamo, 2009; Changeux, 2020).

Finally, although the focus of the game is on brain function at the molecular level, there are important aspects of addiction which exist at psychological and sociological levels. However, such mechanisms are not independent on how our brain is built and how it works, which, in turn, interact with those mechanisms. There is a pervasive tendency to think about the levels of brain structure and these mechanisms as independent. Sometimes, this is expressed as “genes vs environment” approaches and positions, which manifest themselves into questions such as “is this caused by nature, or nurture?” In general, science left behind that sort of discussion long ago. As a striking example, world-renowned geneticists, psychologists and other professionals have warned, for decades now, against separating genes from environment when studying their influence in an organism because they *interact* so the environment regulates the manifestation of genes (Lewontin, 2002; Moore, 2002; Ridley, 2003). Therefore, they cannot be considered independently to explain behavior, and I invite the reader to take a look again at Figure 3 with that new perspective. In due time I will include the relevance of environmental factors of addiction within the video game, and I will encourage players to act in ways that involve neuropsychological executive functions and elements of the environment to train skills, which is more effective than regular strategies to prevent drug use, and mitigate its harm (Stockings *et al.*, 2016).

Future directions also include refining details of exciting story arcs that motivate players to continue learning for many more scenarios, and I should also measure learning in 12 and 13-year-old children and adolescents since they are already using psychoactive substances all over the world (Wang and Hoyte, 2018; Aly *et al.*, 2020; Molinaro *et al.*, 2020). Although conscious memory of meaning is highly flexible, (re)constructive and relational (Duff *et al.*, 2020), the educational purposes of video games in children and adolescents could be tested to a maximum if I include an evaluative phase of long-term learning in the study design.

The challenges the world impose on us demand we efficiently prepare for them. In the case of complex social and personal challenges it is crucial that we, as educators, creatively use layman's terms and strategies to prepare young people. In this study I found evidence that young adults learn the basics of synaptic function with the first scenario of the video game saga 'You VS Drugs'. If we want to reduce the misery drug addiction imposes on families in our societies, we should educate young people in any effective way possible.

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Using In-game Analytics to Explore Learning Dynamics of Information Literacy in a Social Media Simulator

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Abstract: The emergence of Game-Based Learning (GBL) strategies to promote critical thinking has generated a growing need for analytical tools able to assess their effectiveness. Current methods typically apply qualitative approaches such as focus groups and survey-based questionnaires evaluating players' knowledge, skills, and attitudes before and after playing the game; these methods are flexible, and they provide valuable information, yet new methods are needed to improve our understanding of what is happening during a gameplay session. The challenge of understanding the internal dynamics of GBL are illustrated by the open debate on gamified disinformation inoculators. These educational tools teach players how to identify disinformation by training them with a small set of fake news displayed within a gaming experience. There is an ongoing debate on what exactly is being learnt with these inoculators as some studies suggest a positive effect while other ones reveal that they promote scepticism instead of resistance against fake news. It is argued that new analytical methods are required to capture the learning process: detailed data collection on gameplay would be extremely useful to identify the most useful traits of Game-Based Learning, while detecting potential limitations or negative effects of this valuable learning resource. This work presents a novel framework to assess GBL dynamics grounded on data analytics. The approach uses the potential of the Unity in-game analytics platform to collect detailed data on how players tackle the challenges posed by the game mechanics; this diverse information may include the full set of decisions and interactions of the player as well as additional information such as the number of tries or time lapse between interactions. The behavioural data is then combined with content metadata information to infer general learning dynamics amongst players. This analytical framework is applied to a social media simulator included in the video game Julia: A Science Journey. Results suggest that the framework can reveal novel insights including aspects such as the level of engagement of the players, the impact of the type of content on the correct assessment of fake news, and the relation between reading speed and performance.

Keywords: Fake news, Video games, Data science, Information literacy, Critical thinking

1. Introduction

Digital games have become a widespread learning resource in formal education. The mix of narrative, interactivity, and problem-solving mechanics typical of this format can be easily applied to learning contexts to promote critical learning dynamics on complex scenarios involving a diversity of factors and processes. Additionally, playing video games generate a high level of agency which can be used to promote empathy towards life stories radically different than the personal experience of the students (Gee, 2014; McGonigal, 2011; Squire, 2011).

One of the main challenges of the emergent field of digital Game-Based Learning (GBL) is the assessment of educational strategies. The complexity of the interaction between a player and a digital game has no parallel in other formats and for this reason it is difficult to evaluate what has been learnt during a gameplay session (Connolly et al., 2009; Tahir and Wang, 2017). A range of previous works have applied qualitative approaches such as focus groups and documentary research which have been complemented by traditional survey-based methods comparing pre- and post- game skills and knowledge acquisition (Mayer et al., 2014). These studies are extremely valuable to better understand the learning outcomes of GBL yet several questions remain open to further methodological research. First, current methods do not explore the myriad of interactions developed during gameplay; the collection of detailed evidence on in-game player's behaviour may provide relevant insights on the strategies and solutions players devise to progress. Second, these methods are not well suited to capture the diversity of learning dynamics caused by the non-linear format of digital games; each player and gameplay will generate a different learning process because they will choose different actions in different orders. This non-linearity will not be captured by survey-based analysis once the session is over. Finally, these studies are almost exclusively developed in formal educational contexts because they need to collect feedback from the players outside gameplay while a majority of GBL processes happen outside the classroom. Consequently, informal learning dynamics can be hard to capture by these methods.

A session with any digital game is inherently a learning process even if it is not played in a formal context or the player is not consciously using gameplay as an educational resource. A player needs to acquire knowledge about the virtual world where the game develops as well as its story; if they want to develop a successful decision-making process then they also need to understand the goals of the game, to master its mechanics, and to plan based on the predicted consequences of their actions (Rubio-Campillo, 2020). From this perspective a large majority of GBL dynamics will happen in gameplay sessions at home and for this reason GBL studies also need methods applicable to these unsupervised experiences. The assessment of this type of informal learning sessions is always difficult due to their diversity and ubiquity within our daily routines (Galanis et al., 2016; Kerka, 2000; Livingstone, 2001; Vavoula et al., 2005). In the context of the video game industry there are hundreds of new commercial products published every year including content potentially useful for critical learning and formal education such as History, Archaeology, Biology, and Maths; however, the assessment of the learning outcomes achieved by these gameplay sessions is hardly possible. Therefore, millions of players are learning new skills and knowledge at a daily basis, but we do not know exactly what they are learning or to what extent these GBL dynamics are useful for educational goals beyond entertainment.

This work presents a novel research framework to study GBL dynamics based on the use of in-game data analytics and information visualization. The approach has been implemented in Julia: A Science Journey (JASJ), a digital game designed to promote critical thinking about the social impact of the COVID-19 pandemic. We present here the analysis of a minigame included in JASJ with the aim of promoting discussion on the use of social media and the impact of fake news in scientific knowledge. Next sections present the game and the fake news minigame while section four discusses the analytical framework implemented within the game. Section five discusses the results of the work, and the paper concludes with some thoughts both on the disinformation minigame and the use of the framework beyond this case study.

2. An overview of Julia: A Science Journey

The project DiHealthEd (2021-2022) was a research grant funded by the Catalan Research Agency (AGAUR) to use digital games to promote critical thinking on the impact of global emergencies within secondary education classrooms (DeJong, 2023; Fernández Galeote and Hamari, 2021; Squire, 2008). The main output of the project was Julia: A Science Journey (JASJ). JASJ was designed to be used in formal contexts and for this reason the game's contents were aligned with the Catalan secondary curriculum. JASJ was developed in 18 months by Murphy's Toast Games, a small, experienced studio specialized on transformative learning experiences (Rubio-Campillo, 2020; Rubio-Campillo et al., 2017). The game was released in Fall 2022, and it is freely available for Windows, Mac, and Linux operating systems both as a direct download and a Steam product since March 2023.

JASJ is structured in a set of episodes that can be independently played to facilitate use in 10-15 minutes sessions within the classroom which can be further enriched by a discussion supported by an Educator's Guide published in the game's website. The game can also be experienced in a conventional way with an average gameplay duration of two hours. Each of the episode depicts an animated scene, a dialogue, or a minigame focused on a specific topic such as science, the comparison between the COVID-19 and the 1918 Spanish flu pandemics, or the expectations of young adults towards their own future (see Figure **1**).

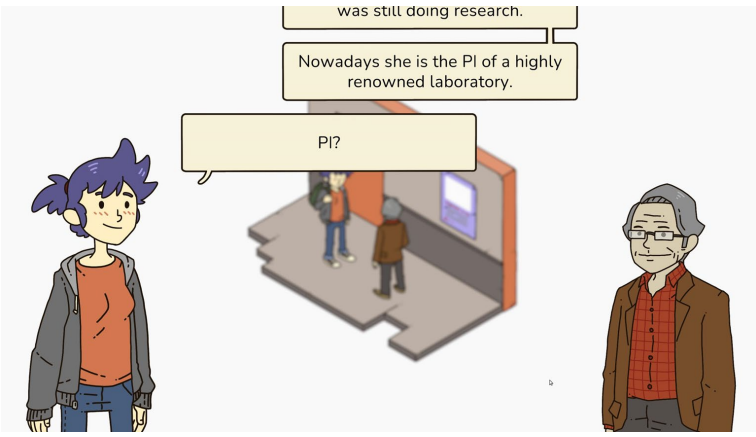

Figure 1: Storytelling in JASJ is developed through interactive dialogues

There are three types of minigames. The Presentation minigame is a metaphor for acquiring and communicating scientific information using two complementary mechanics: a) a quiz based on logical reasoning and curriculum

content, and b) a platformer where difficulty is based on the player's performance in the previous quiz (see **Figure 2**). The Rider minigame is a cycling game designed as a reflection on the social climate and measures taken by different governments during the lock-down (e.g., wearing facemasks in open public spaces, see **Figure 3**).

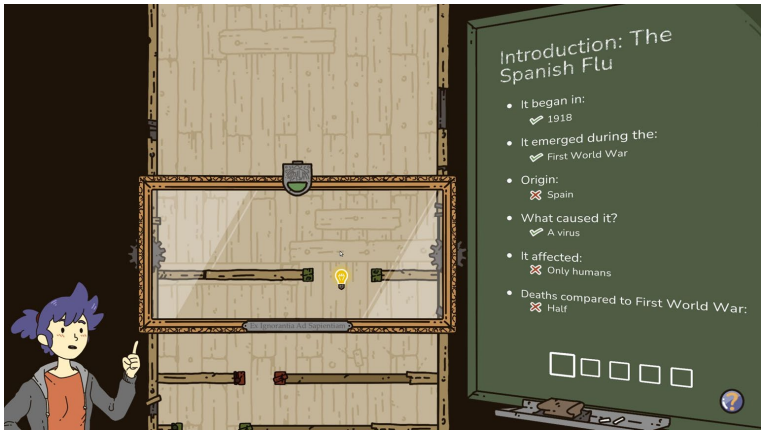

Figure 2: The Presentation minigame starts with a quiz including secondary curriculum content (right side); the rate of success in the quiz will define the difficulty of the platform level (left side)

Figure 3: The Rider minigame promotes discussion on the social dynamics caused by COVID-19 lockdown measures

Finally, the Quacker minigame simulates a Twitter-like social media network where users must report any Fake News shared in their wall. We discuss now this minigame as it will be used as a case study where explore GBL dynamics using in-game analytics.

3. Quacker: A Fake News Minigame

One of the current barriers to critical thinking on current global emergencies such as the COVID-19 pandemic and climate change is the growing presence of uncertain and false information shared via social media platforms. Social media engagement with controversial topics promotes a better understanding of their complexity yet approaching them require a solid understanding of scientific evidence, skills to prioritize information in digital contexts, and a key competence on identifying disinformation (Jiménez-Liso et al., 2020). An innovative strategy to train these skills is based on the concept of inoculation: if an individual learns how to identify fake news within a controlled context, then they will be able to perform the same task in real conditions. In this context, GBL is an ideal disinformation inoculator thanks to the use of interactivity and storytelling to present complex virtual scenarios (Lewandowsky and van der Linden, 2021). Quacker uses this approach to generate an educational interdisciplinary experience while reflecting on the social dynamics of the digital world by combining scientific content with themes such as mental health, toxicity, and popularity.

The Quacker minigame is integrated within the narrative of JASJ as it appears whenever the main character, Julia, is checking her phone. In this moment a new UI is shown displaying an app like twitter as can be seen in **Figure 4**.

Figure 4: Quacker is a social media simulation where users need to report fake news

Quacker's user experience has three main components: a) a short text message posted by a user (i.e. a quack), b) three possible reactions to the quack to be chosen by the player (report a fake new, like, or dislike), and c) two game stats: Julia's mood (i.e. mental health) and number of users (i.e. popularity). Each quack is internally coded with three variables: a) a Boolean variable defining if the quack is fake news, b) its level of toxicity, and c) its impact on Julia's popularity. The goal of the game is to react to 10 quacks while reporting fake news and balancing Julia's stats. On the one hand, the player needs to report all fake news while avoiding false reports; three strikes will end the game, thus forcing the player to replay the game with 10 different quacks. On the other hand, the toxicity of a quack will affect Julia's mental health while its content will change the number of her followers; the decrease of any of these stats below a certain threshold will become a failed state and force a replay. If the player can react to 10 quacks while avoiding this fail conditions, then they will receive a score of 1 to 3 stars based on performance. These game over and success screens also display ironic messages discussing the concepts of popularity and toxicity to reflect upon player's strategies (e.g., share controversial content to attract more attention).

Quacker is part of a growing amount of GBL approaches to disinformation inoculation which seem ideally suited to promote critical interdisciplinary thinking (DeJong, 2023). However, the effectiveness of the approach is still open to debate as recent works suggest that fake news inoculators promote scepticism instead of disinformation inoculation (Modirrousta-Galian et al., 2023); these unequal results suggest that the field needs larger sample sizes and better analytical methods to improve our understanding of how a player learns to identify fake news. The strategy deployed in JASJ was the development of in-game analytics designed to improve our understanding on the learning pathways followed by players across the gaming experience.

4. Analytical Framework

In-game analytics are data-driven frameworks designed to collect and analyse player's performance and behaviour within a digital game (Su et al., 2021). The exploration of in-game data allows game studios to gain insights on the player's experience to identify issues, improve gameplay, or optimize monetization. Beyond these traditional uses, in-game analytics can also be used to assess the learning outcomes of serious and educational games either using data visualization or more formal evaluation processes (Alonso-Fernández et al., 2019; Callaghan et al., 2014; Cano et al., 2019; Hauge et al., 2014; Loh et al., 2015).

JASJ used the Unity Analytics framework to collect data on player's behaviour across gameplay sessions. The data collected during a Quacker run tracked variables such as the player's reaction to every quack, the amount of time spent before reacting, and a diversity of summary statistics (e.g., number of strikes, Julia stats, replays). Data collection begins with the creation of a list of Events using the Unity analytics dashboard. These events can be sent by the game to the Unity servers whenever required via the API functions designed for this task. Two events were defined to assess Quacker: a) Quack and b) QuackSummary. The first event provides information on how a player reacts to a quack by including common in-game stats (e.g. user ID, timestamp, platform) and custom fields such as a unique **identifier** for the quack that the player is interacting with; the **action** of the player which may have the value of like, dislike, and report; the stats of **popularity and toxicity** at the moment of this interaction; and the number of **strikes** (i.e. wrong fake news reports) at the moment of this interaction. The second event was submitted at the end of a Quacker run and provided summary information on the player's actions such as a unique **identifier** for the run; the final **score** after 10 quacks ranged from 1 to 3 stars; the

fail/success state; and the stats of **popularity and toxicity,** and **number of strikes** at the end of the run. The published version of JASJ includes a diversity of events similar to the ones described here to assess a wide range of player's behaviour during sessions; this anonymous data collection was made explicit in the first screen of the game, so players are aware of the process.

The Unity Analytics framework allows the developers to access the recorded events using a variety of dashboard visualization and SQL queries. This last option was the one chosen by the authors to explore GBL dynamics in Quacker. Specifically, the analysis focused on three questions: a) to what extent are players engaging with Quacker?, b) what type of content is harder to assess?, and c) is there a relation between reaction time and performance? These topics were explored within informal learning contexts by collecting the complete list of events submitted during Quacker gameplay for a sample of over 112 players. The dataset collected a total of 3565 quack interactions of 436 runs excluding abandoned runs and communication errors.

5. Results

Figure 5 shows the time series of Quacker runs included in the dataset since the release of JASJ in Fall 2022. The increase on the number of runs during Spring 2023 is caused by the release of the game in the Steam platform which is the main digital distribution platform for PC games.

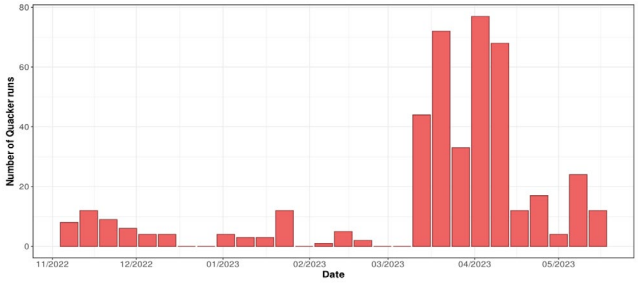

Figure 5: number of Quacker runs made by the sample of 112 players since September 2022 until April 2023.

The average number of runs per player is around 4 with a majority of users playing Quacker up to 3 times while a small number of players made over 10 runs. This replayability suggests a good level of engagement because users may continue with JASJ after the minigame even if their score is just 1 star (the minimum); a large percentage of players decided to continue playing until they achieved the best possible score of 3 stars while some players continued after getting a perfect score possibly to read all possible quacks (every run randomly displays 10 quacks over a pool of 30). This behaviour is independent of the type of player; most of the runs before Steam release were done by individuals who found the game through the science outreach portals where JASJ was advertised or received information shared by official social media accounts (e.g., University of Barcelona, Murphy's Toast Games). Once the game was released on Steam then the type of player changed towards gamers interested on narrative fiction and puzzles, yet the number of replays remained constant, thus suggesting a similar level of engagement.

The second question explored what types of social media content is more prone to be misclassified (i.e., fake news not being reported, and non-fake news being reported). **Figure 6** shows the percentage of player's reactions (report, like, or dislike) per quacks.

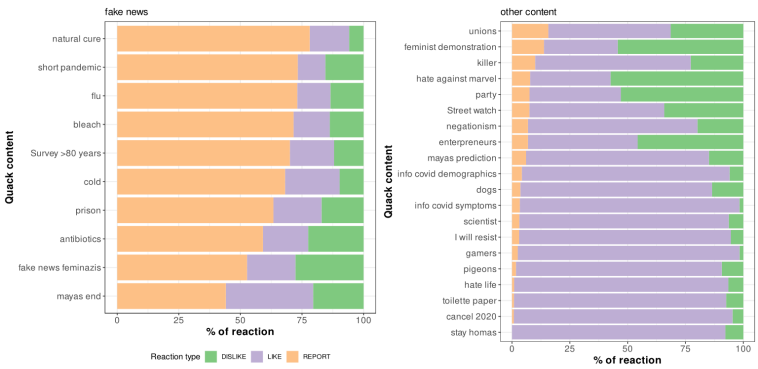

Figure 6: Percentage of player's reaction per quack; quacks are grouped by fake news/other content to facilitate comparison

Fake news more easily identifiable are the ones describing pseudoscience and false information linked to the COVID-19 pandemic (e.g., comparison between COVID-19 and flu). In contrast, disinformation related to political opinions has a higher rate of misclassification. For example, Figure 7 shows a quack linking International Women's Day marches with COVID-19 outbreaks which was incorrectly classified as a fact by over 50% of the players. The same pattern is seen in the opposite direction if at a lesser degree: quacks with facts mixed with political content were often misclassified as fake news for 10% of players.

Figure 7: Disinformation linked to political opinions such as feminism is more prone to be misclassified as facts

The analysis also suggests that players use the source of the quack as a proxy to prioritize information. In the minigame each quack includes a username and an avatar that the player can use to identify its source. Information provided by the World Health Organization was typically liked and not reported while similar content shared by suspicious accounts (e.g., individuals, associations against science) were reported even when they were opinions and not false information. Finally, quacks with content unrelated to politics (e.g., songs, jokes) were liked by most players.

The third question focused on the time players spent reading the quack and thinking before reacting to its contents. **Figure 8** reveals that how fake news and quacks with controversial opinions (e.g., political ideas, toxic messages) generated higher engagement rates as they spent more time before deciding how to react. Jokes and neutral content such as music lyrics required lower reading times before decision as players liked them to improve their game stats once they quickly decided not to report the content as disinformation. These results suggest that reading times are positively correlated to the complexity of the content which suggest an effective interaction between the player and the game; in fact, higher levels of engagement on complex or controversial social media content was one of the main expected learning outcomes defined during the design of Quacker.

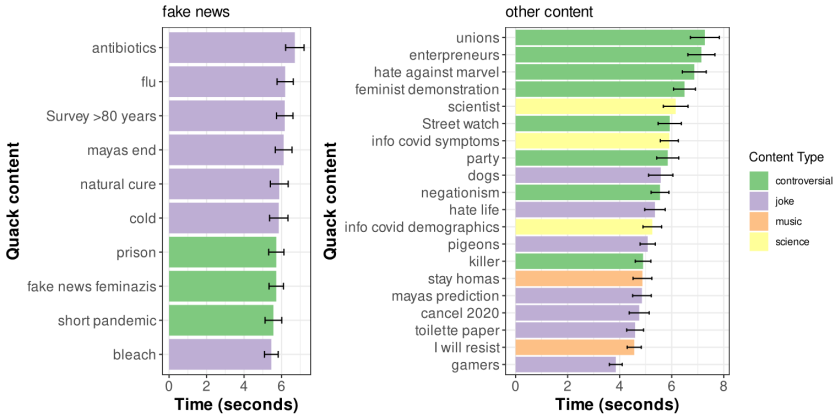

Figure 8: Average and standard deviation values for reading time per quack. Each quack is coloured by its type to facilitate comparison

This interpretation is enriched by **Figure 9** which displays the average reading time in a run compared to its final score. A negative correlation can be observed between player's performance and reading time as runs with

higher scores display shorter reading times which equal roughly 50% difference between failed attempts and runs achieving the highest score (3 stars).

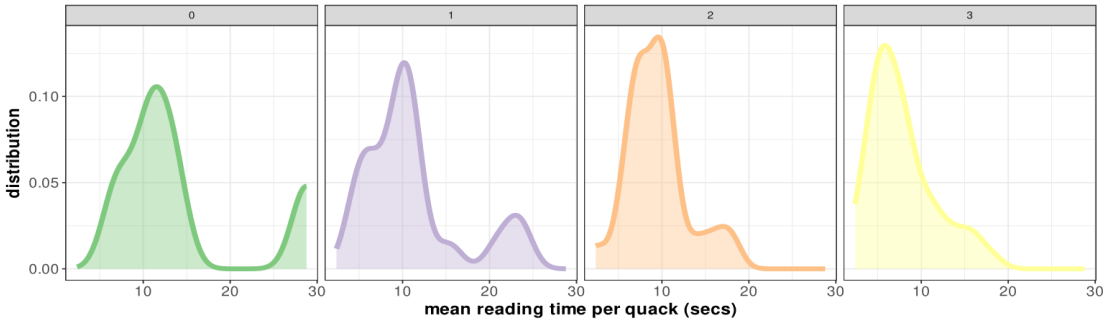

Figure 9: Density distribution of reading time per each score (0=game fail, 1 to 3 stars)

This pattern suggests that reading comprehension is linked to reading speed which is a working hypothesis currently subject to debate particularly in digital environments (Dyson and Haselgrove, 2000; Ekasari, 2021). An alternate plausible hypothesis is that players with higher levels of engagement repeated runs to improve their early scores, thus learning how to quickly identify disinformation and decreasing average reading time. Further research will be needed to explore the full learning process to better understand how players learn how to identify disinformation in social media contexts.

6. Conclusion

The data-driven analytical framework deployed in JASJ has revealed interesting insights on how players assess disinformation within controlled environments such as the Quacker minigame. The wealth of data collected from in-game player's behaviour allows researchers to study dynamics challenging to capture by other methods as exemplified by the combined analysis of reading times, type of content, and final performance. In-game analytics approaches can also be enriched by pre- and post-game surveys and player's feedback gathering which may even be integrated within the same game; in fact, JASJ includes an initial survey collecting anonymous information on the previous gaming experience of users which will be used in further studies in combination with in-game behaviour.

This work also shows the advantages of using tailor made digital games over commercial non-educational games as learning resources; the collection of in-game analytics is only possible if researchers have access to the development team because events must be called from the source code of the game. This is a limitation for initiatives willing to use commercial games as their main learning resource; this issue can be mitigated by the creation of mods collecting in-game data whenever possible (Yee, 2014), but the level of detail data will hardly be achieved by these technological solutions.

GBL strategies have proven to be an asset for learning complex scenarios by using the mix of narrative and interactivity that defines the gaming format. The increasing number of existing GBL experiences require a similar growth of analytical methods able to cope with the complexity of digital games. These techniques are already available to developers even if the original goals for in-game analytics have nothing to do with educational research. This paper has exemplified how these tools can be used within a data-driven analytical framework particularly suited to study GBL dynamics in unsupervised informal contexts. Ultimately, we hope that the analytical framework deployed in JASJ can contribute to a better understanding of the full complexity, diversity, and richness of GBL experiences within and beyond the classroom.

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A 3 Roles' Model to Better Design and Facilitate the Use of Serious Games in the Classroom

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Abstract: The use of serious games in education, whatever the level of students and the subject of study, is full of promise but also strewn with obstacles. Both aspects have been the subject of numerous studies, a number of which underscore the multiple roles teachers have to embrace, each of them representing a more or less difficult challenge. Many factors come into play, including teachers' familiarity with this particular kind of tools.-The research work presented in this article includes both game designers and university teachers in the field of management. Serious games have been used in classroom during a 6-year experiment. This experiment reveals a set of teacher attitudes that have to be adopted during teaching sessions to make the most of an increased students' engagement. Teachers are led to adopt roles and positions they are not always familiar with, which can lead to certain difficulties or frustrations. How can we better take these new roles into account? Is it possible to turn them into a strength, and to take them into consideration beforehand, when designing teaching sessions, so as to optimize the use of serious games and get the most benefit from them? Finally, we propose to build a grid of these roles, which describes each of them, its benefits and its limits, and provides guidelines to avoid common pitfalls.

Keywords: Teacher roles, Serious games in the classroom, Management simulation, Game master

1. Introduction

Some teachers embark on the use of serious games in the classroom having in mind the benefits often associated with the approach. At the very least, this modality is considered to have a positive impact on both rhythm and variety of the course. Most importantly, it engages students, motivates them, and, in fact, promotes learning.

But this approach also implies changes in their role that teachers do not necessarily anticipate. They often devote most of their time and commitment to technical implementation and discovery of the serious game, to the detriment of a thorough reflection on the course of the session. It is only when the actual course takes place that teachers realize, more or less implicitly, the emergence of new relationship patterns between them, the serious game and the students. They discover that they must adapt their stance to account for this specific scheme, in order to avoid certain pitfalls and make the most of the situations.

We found it important to explicit these schemes and the (sometimes new) roles that teachers need to play in each of them. These roles have been the subject of several studies, in which teachers have been requested to point them out by themselves after having used serious games. We propose a methodology to help teachers do so beforehand, and take these new roles into account in the very process of designing their sessions.

The question we ask is therefore the following: can teachers reverse this experience and define in advance the roles they will have to play? Could this be a way for them to not only better master these roles, but also to make them a tool for designing the session, in order to get the best out of the use of the serious game?

In chapter 2 of this article, we will study the state of the art on teacher's role in serious-game assisted pedagogy. Chapter 3 will present our proposal by describing each role. The fourth part will focus on the implementation and application of this model to a serious game that has been used for 6 years, and its results based on questionnaires submitted to the protagonists. The last chapter will be dedicated to discussion and conclusion about this work.

2. State of the art

Our research focuses on the roles played by teachers in the use of serious games.

Different roles can be played by teachers when using serious games in the classroom. The technical and administrative environment alone can be a major obstacle, because it requires specific skills that the teacher does not necessarily possess, as well as a significant amount of time and involvement.

Two research articles address the issue from the perspective of the kind of support to be given to teachers adopting serious games.

The first one, titled « Supporting Teachers in the Process of Adoption of Game Based Learning Pedagogy" (Emin-Martinez & Ney, 2013) wonders how *"the adoption process unfold when teachers introduce games in their classes for the first time?"*. The article describes the different stages that lead the teacher to adopt the use of Serious Games as an innovation. The second one (Wolfgang G., 2016) lists points "*which all institutions have to go through for successful implementation".*

These articles confirm that different kinds of obstacles can be encountered on the teacher's path.

Beyond these aspects, the mere use of a serious game in the classroom also requires teachers to adapt to new situations for which they must be prepared.

Three articles focus specifically on the role of the teacher during the use of serious games in the classroom.

In "Teacher Roles and Positionings in Relation to Educational Games" (2010), (Hanghøj and Brund define three pedagogical approaches with different roles played. Four roles are specifically interesting in our context.

- Instructor: "teachers attempt to plan and communicate the overall goals of a game scenario in relation to particular learning objectives"
- Playmaker: "teachers' ability to communicate the tasks, roles, goals, and dynamics of a particular game scenario as seen from a player perspective"
- Guide: "how teachers support or scaffold students in their attempts to meet particular learning objectives when they play a game"
- Explorer: "understand, evaluate and provide dialogical response to the students‟ experience of playing a game – as seen from an outsider's perspective"

We agree with the above authors on the observation that the different teacher's roles all include constant interaction: *"teacher roles should not be seen as fixed ''scripts'' or functions, but rather understood as more or less stable patterns of interaction and expectations that are based upon processes of continual negotiation – i.e. between a teacher, a game scenario, and his or her students".* The **Instructor** role is core to any teacher's practice and therefore not specific to the context of serious-game based pedagogy. It is nonetheless fundamental.

The three other roles describe in detail how the teacher establishes the link between students and the game, and supports them during their game experience. In our opinion, this distinction is not required and these roles could be regrouped under a unique term corresponding to a "**Game Master**" function.

(Molin G., 2017) offers an overview of the research conducted on the issue of roles, and concludes that *"the role of the teacher in game-based learning needs to be crucial as well, which also means that game-based learning could be an opportunity to empower teaching and to create new meanings of the role of teacher in the digital age*".

In particular, it mentions the different roles documented by (Silseth, 2012) and summarized by (Shah and Foster, 2015):

- Expert: "help students making connections with the learning goals."
- Facilitator: "facilitator of pedagogical approaches such as instruction, discussion and observation to provide space for reflection and feedback"
- Connector: "to help students to see and understand the relevance of their acquired knowledge beyond the classroom"

The **Expert** role is obviously key, in any teaching context. Nonetheless, we consider that the Facilitator and Connector roles could be seen as part of this expert role, or at least directly associated with it.

(Marklund and Taylor, 2015), describes a several months study identifying teacher's roles along the learning process: "*The study identifies the different roles that a teacher takes on throughout game-based learning processes, such as technical administrator, game administrator, game tutor, subject matter expert, lecturer, debriefer, and classroom supervisor"*.

In this article, we retain a specific point of view about in-class facilitation, which highlights the necessity of a better context understanding in order to improve the use of these games in the educational system.

In confirmation of this conclusion, our own findings point out three following behaviours:

- Game tutoring: guide and support students' gaming experiences during gaming activities
- Authority & enforcement: help reinforce the educational framing of the gaming activity.

- Anchoring on the subject: bridge the gap between game content and the details of the subject matter the game is intended to illustrate.

Similarities appear between the description of these roles and a few others that we have already mentioned, with only a change of perspective. The "game tutor" corresponds to one aspect of the Game Master role and anchoring ca be seen as more specifically attached to the Expert role.

A last article does not focus on the use of the serious game but in a general way on learning postures (the authors use this name instead of role), "Teaching skills: a multi-agenda of embedded concerns, a set of dynamic interactions between teacher's scaffolding postures and pupils' learning ones" (Dominique Bucheton & Yves Soulé, 2009). This article identifies 5 central concerns from a ''teaching skills point of view":

- pilot and organize the progress of the lesson,
- maintain a space for language and cognitive work and collaboration,
- to make sense of what is going on,
- supporting the work in progress, itself described by "supporting postures".
- all with a focus on learning of any kind.

As mentioned, the fourth behavior is close to our concerns about the "posture" concept and four corresponding or expected behaviors:

- a controlling stance: by closely monitoring the progress of the tasks, the teacher tries to get the whole group to move forward in synchrony.
- a counter-supporting posture: the teacher, in order to move forward more quickly, if necessary, can go so far as to do things in the pupil's place.
- an accompanying posture: the teacher brings, in a lateral way, a punctual help,
- a letting-go posture: the teacher assigns responsibility for their work to the pupils and authorizes them to experiment with the paths they choose.

We do not take up any of these roles directly, but their definition, in particular that of "supporting postures", seems to make sense for our purpose and will help define a model, even if it was not intended specifically for a serious game context.

In summary, this state of the art analysis demonstrates that some of these roles overlap, and the proposed taxonomies vary according to the points of view, but they all converge on the missions that the teacher must fulfil:

- communicating the tasks and objectives to be fulfilled,
- assisting students to achieve them,
- maintaining a learning environment,
- creating links between the game and learning objectives.

The 3 roles that we describe in the next section account for all of these missions, while offering both a synthesis and additional dimensions.

3. A 3-Roles Model Proposal

The state of the art shows us that the roles identified allow for a detailed analysis of the way in which the teacher positions himself in order to create links between the learning object and the serious game (Wake, Dysthe & Mjelstad, 2007). In other words, it is the pedagogical dimension that is at the heart of the topic.

However, these contributions seem to be missing a mission that, on the contrary, appears essential to us when using a serious game: offering a genuine game experience to students. The implicit contract established as soon as the word "game" is used must be respected, and the game can't do it alone.

As we will point out in the next section, direct observations and students answers to our surveys show it well: the commitment generated by serious games is real, but the links with learning must be woven and closely held by the teacher.

This is why, at the end of this analysis and in the light of our experimentation, we propose to retain only 3 essential roles that we identify and describe in the next section. From our point of view, and in our research context, including recent or new "Serious Game adopters", it is important to propose a clear and simple model.

These 3 roles are always at play. Bearing them in mind from course-design stage and at all times during learning sessions can empower teachers with useful references.

The first fundamental role we want to put forward is specific to a mission that we will call the ‘‘**Pilot**”. The next one corresponds to the “**Expert**” and the last one has been called the "**Game Master**".

3.1 The Pilot Structures The Session and Ensures That it Runs Smoothly

The Pilot’s role is to set up and maintain the learning framework, i.e.: plan and implement the session structure, define detailed processes for each sequence, end instructions to be communicated to learners. It covers everything from designing the outline to precisely shaping the thread of the learning session, while ensuring a fully controlled use of the serious game and a clear perception of its learning function.

In other words, the serious game must find its place in the learning session in a fluid manner, and its role as a learning tool must be perceived and understood by the students. In our model, the "authority and execution" mission put forth in the above state-of-the-art analysis, is also part of the Pilot’s role.

3.2 The Expert Makes the Connection Between Game Experience and Learning

The serious game cannot be the only vector of knowledge, know-how or soft skills defined as objects of learning. The teacher is also responsible for creating links between the game experience and the targeted educational objectives. Here again, the methods and time allocated to this work must be thought out in advance. The difficulty in using a serious game is to give the "right" place to this expert role.

The objective is to use the game experience to make the knowledge acquired from the serious game visible and valuable, and to use it as a basis for further study of the subjects covered.

3.3 The Game Master Provides a Playful Experience For Students

One of the proven advantages of serious games is their ability to engage students. In turn, this requires that the playful dimension of the tool be fully exploited. Specific questioning and facilitation mode choices have to be made by the teacher beforehand.

The challenge is to set up a genuinely entertaining experience for the students, while aiming at "serious" objectives at the same time.

Among all missions, this one is certainly the most field-specific, therefore unfamiliar to the teacher and potentially delicate to carry out. It is also the one that can be sized differently according to the teacher's level of mastery of the serious game.

Based on our experiment, we observed that these three roles are interrelated, which makes them contribute equally to the overall objective. Therefore, the teacher must keep them in mind simultaneously at all times, give them the same importance, and address the questions associated with each of them in advance. This is the only way to better master the use of the tool, to benefit from game playfulness and a higher commitment of students, and thus to get the most out of it in terms of learning.

3.4 The Guidelines

The following table is a suggested guideline for implementing these three roles. For each role, it includes:

- sample questions to be asked beforehand
- recommendations and suggestions for implementation

The PILOT This list of questions and recommendations constitutes the essential basis for implementing a serious game in the classroom.
What questions to ask? - How do I keep control of timing? What timing constraints does the game impose on me? - How to articulate times of play with periods of transmission / in-depth study of considered knowledge? Can playtime easily be divided into self-contained sections? - Can a progression curve be set up for structuring the session? Does the game also feature a level-up experience?

What are the best practices to rely on? *Before the session:* - Test the game to master its structure: minimum duration, maximum duration, key stages, replay possibilities, risk of losing, ease of winning... Your objective is not to extensively explore its content, but to clearly understand how to use it and when. - On this basis, plan the session structure by anticipating anchoring times. If the game allows, plan to alternate game and anchoring times. - Try to figure out the reasons of technical constraints encountered in the game; try to estimate the benefit versus time spent and risk of difficulties or failure ratio you might face, and free yourself from these constraints if possible. In other words, focus on simplicity and fluidity. *During the session:* - Clearly and precisely establish expected result of each sequence of play, and condition for stopping, continuing or repeating. - Formulate resulting instructions.

The EXPERT This is the keystone role played by the teacher, who must above all ask themselves what they expect from the serious game in terms of learning. This analysis will later help calibrating how they invest in the Game Master role (see next table).
What questions should I ask? - What are my learning expectations? A recreation, a simple playful way to illustrate a topic? A stimulus, a way to introduce a topic? A basis for debate? A transmission of knowledge? An evaluation tool?... - What game elements are in direct relation to my learning goals? What can I expect from the game in terms of learning? - Are these elements explicit in the game or do they have to be inferred?
What are the best practices to rely on? - Identify the direct links that can be established between the learning object and the serious game. - Calibrate this identification work with your expectations - Adapt the instructions to your expectations and draw up a clear contract with students: the higher the educational expectations, the more precise and demanding the instructions should be. - Express the instructions before the game experience so that students keep a fresh memory of them while playing and do not risk to get confused. - ... while ensuring that they do not turn the game experience into work: allow for the possibility of playing twice, or allow time for reflection after the game. - Solicit the students' critical thinking: instruct them to synthesize, question, comment on, criticize... the serious game in order to exploit it, including its limits and weaknesses - Encourage and exploit exchanges: during game time if students are divided in subgroups during full class working time

The GAME MASTER This role is likely to vary largely depending on the teacher's familiarity with the serious game and their ability to use it. The teacher should objectively position themselves on an axis graduated from Basically Trained User to Experienced Game Master, according to their experience, motivation, rehearsal effort they will need to invest to master facilitation, support they have access to. It is a choice that they must make consciously, with the aim of benefiting from the serious game in all cases.
What questions should I ask? - What exactly do I need to know about the game to achieve my goals? Knowing the model on which the serious game is based is not a matter of necessity, but it will give the teacher more leeway and ease in dealing with unexpected events and student questions. It is therefore a matter of calibrating the level of mastery of the serious game according to what is expected of it. - Do I know precisely the rules of the game and its gameplay? - Can I change them? - Are there particular points I want to draw the students' attention on? - How can I get the students to play? Does the game impose a unique starting point, or does it allow for open possibilities that I can build upon?
What are the best practices to rely on? *Before the session:* - Imagine all possible modalities: individual, subgroup or full class game teams - Consider their resonance with the identified expectations - If the game breakdown allows and if the session is long, try to vary modalities over time to avoid repetition or boredom. - Include times fully dedicated to a free experience of playing, during which students may act and behave at will. *During the session:* Adopt a clear position towards the serious game: Depending on the field taught, warn that the serious game is not an expert, and should rather be seen as an opportunity to provoke debate. Generally speaking, explain the role that the serious game will play in learning. If necessary, inform students about the difference between the level of difficulty of the serious game itself and the level of mastery expected from them. During independent play time: Clearly state beforehand the instructions to be followed and the condition for stopping. Do not intervene during play time, except at the request of the students. Dissociate the game from the pedagogical issue (winning is not necessarily the best way to learn): Let students seek to win and be satisfied with having done so but offer related goals to encourage them to explore and test different strategies if the game allows. As part of your facilitation strategy, take advantage the elements provided in the serious game that refer directly to the game universe: scores, rankings, objectives to be fulfilled, life/action points...

4. Use case: A 6-year Experiment

4.1 Description

Over the last 6 years, the same experimentation has been repeatedly carried out and progressively enriched. It consisted in taking 3 serious games dedicated to managerial situations as a central part of 2 tutorial sessions.

One the games was based on remote-management challenges, the second one dealt with conflict management, and the third one with the subtleties of giving feedback.

- The “Remote management” game provides 3 successive missions. The learner-player is provided with action criteria like rhythm and content of meetings, level of feedback, mutual aid, reporting... each setting impacting the efficiency and cohesion of the team. The level of difficulty increases across missions, and each successive mission must be completed in order to access the next.
- The “Conflict management” game focuses on an interview between a disgruntled employee and her manager. This time, it is about steering the dialogue by orienting a virtual manager’s attitude towards more or less sympathy, empathy or antipathy (authoritarian attitude) over the employee. Possible outcomes of the dialogue range from fully breaking up to perfectly restoring the manager-employee relationship.
- The “Feedback” game challenges the player with accurately qualifying the way a positive feedback is given (tone, precision, listening), and then conducting a dialogue to build corrective feedback (using the same principle as above).

Some preliminary elements:

- For these two sessions, from the first year, the choice was made to simplify the technical aspects as much as possible:
- A standalone version of the serious game is available to overcome any connection difficulties. No feedback or centralization of scores or progress is set up. Everything takes place during sessions, limiting preparations and follow-up as much as possible.
- We have deliberately excluded individual use of the serious games from the beginning of the experiment.
- The scores obtained within the serious games were explicitly and totally disconnected from the teaching and its evaluation. The goal is for learners to freely test all strategies, including the worst ones.

Different modalities have been tested during over the years, but a same set of modalities was systematically implemented across all groups concerned during a specific school year, i.e., about 150 students per year.

Here is a summary of the pedagogical modalities we have implemented. For each of them, we have indicated 1 or 2 of the 3 roles that predominate.

Collective play	
The group collectively plays simulation (conflict management): the teacher specifies that they do not expect a “good” answer, but a reasoned position. They provoke and lead debates, without ever taking a position. The class ends up voting and validating the choice of the greatest number.	
Roles of the teacher	1 – Pilot: they distribute the groups, decide when to vote, ensure the timing. 2 - Expert: they take every opportunity to provide clarifications and create links between what the course of events and notions to acquire.

Play in pairs with instructions	
The students are grouped in pairs and play independently: they aim at fulfilling the mission assigned to them by the game, but also at following a precise pedagogical instruction (note key actions, raise points of disagreement, etc.). The teacher states this instruction and ensures that it is not forgotten during the game sequence.	
Roles of the teacher	1 – Pilot: ensures that students move forward in the game, that they have understood and retained the instruction, and responds to any request they may have 2 - Game Master: lets students make the most of the game experience while observing their progress and taking advantage of each of their requests or idle times to revive them, encourage them to test other strategies, etc.

Free pair play	
Again in pairs, students play in fully free mode: they test strategies, make random choices, in other words they explore. The teacher directs their missions if they deem it appropriate (for example, a buddy who would have quickly completed the missions is invited to start again by seeking to obtain the worst possible score), and above all they answer questions and comments, which are usually flowing.	
Roles of the teacher	1 - Game Master: becomes the priority in this modality. The freedom of play granted to the group is predominant.

Collective debrief	
Group debriefing at the end of the game is conducted in pairs: general questions are asked, such as "What stands out in your mind?", "What did you think was important?", "Surprising?" ... If a specific instruction was given for the sequence in pairs, it is specifically addressed during the debriefing sequence. Every idea or opinion expressed by students is picked up on by the teacher to create links between the serious game experience and the knowledge to be transmitted, and to deepen related notions.	
Roles of the teacher	1 - Expert: it is above all a question of providing knowledge 2 - Pilot: makes sure that this debrief takes place in a lively and interactive way

Theoretical presentation	
The teacher presents concepts: theoretical notions that were implemented in the game session are exposed. This is a traditional class session, during which the teacher transmits knowledge by illustrating it whenever possible with examples from the serious game.	
Roles of the teacher	1 - Expert: it is exclusively a question of providing knowledge, in a traditional scheme

Over time, we have gradually built the good practices listed in section 3. We based ourselves on our observation of the behavior of the groups, in particular their involvement in the different sequences, and the richness of their exchanges during the debrief sequences.

Here are the main points that we were able to observe in a systematic way:

- The level of interaction is high: between students and the game, between students themselves, and between students and teacher.
- The variety of formats makes it possible to transmit educational messages in several complementary ways: via instructions, facilitation, dialogues, feedback, debrief...
- Exploitation of gameplay (missions, objectives, difficulty levels, challenges, score...) values and legitimizes the use of serious games. The more students feel like they are playing, the more they get involved and enjoy it.
- However, if they are not given explicit instructions for a learning objective, they focus exclusively on achieving the highest possible score.
- Traditional course sequences are perceived in stark contrast with game sequences, and it is difficult to maintain their connection and fluidity.

We supplemented this observation with two questionnaires. The first one was used over 4 years and allowed us to identify the students' feelings about serious games. We then focused our questions on how they perceive the role of the teacher during these sessions. It is this second questionnaire that is of particular interest to us here.

4.2 Evaluation

We will just extract one point from the first questionnaire: more than 80% of students "agree" or "completely agree" with the three statements "The serious game makes the course more pleasant (1), lively (2), and modern (3)".

At the very least, this result is an encouragement for teachers to persevere in their use of serious games in the classroom.

Here is the information we have retained from the 2nd questionnaire:

1 - Role of the teacher

It is globally: the same as in class (1), different from the one they have in class (2), it depends on the sequences (3).

The 85% of students' responses are evenly divided between answers 2 and 3. Very few consider that the teacher's role is the same as in class.

2 - Collective game sequence

The teacher transmitted knowledge to you: based on the game (1), without any real link with the game (2), did not transmit any knowledge (3).

(1) received 92% of the votes. The transmission of knowledge during the simulation is well perceived, as well as the link with the game.

3 - Link between theoretical presentation and serious game

The lecture that followed the simulation: was not really related to the SG (1), talked about the same thing but not related (2), talked about the same thing and made the subject clearer thanks to the SG (3).

(3) was chosen by 81% of students. Again, the link between the game and the knowledge imparted is well woven.

4 - Perception of the different sequences

Students were asked to choose the sequences they appreciated the most, in terms of learning on the one hand, and pleasure of use on the other.

The 2 modalities at the top of the students' answers are the realization of the first serious Game in subgroups, and the simulation played collectively.

The vast majority of students rank the games that they learned the most from and the ones they preferred in the same way. This tends to show that they equate pleasure and learning.

5. Discussion and Conclusion

In this article, we proposed a 3-role model to describe the teaching attitudes that a teacher should be aware of and adopt during a serious game session in the classroom. Our goal is to help them by identifying a priori the roles they have to play: Pilot, Expert and Game Master. We have chosen to focus our reflection on the roles that the teacher plays when running a session.

The list of roles that we propose is deliberately reduced, to make it easier for teachers to use it as a guide.

Our second concern in the construction of our proposal was to put forward the playful dimension of the serious game. Our experience has shown us to what extent the term "serious game" can raise expectations (from students), fears (from teachers), and frustrations (from both). We therefore propose to take into account this implicit promise of the term "serious game" in the identification of teacher's roles.

This is why we distinguish between a role of "Expert", focused on learning, and a role of "Game Master", focused on the game experience. In the description of the Game Master role, we consider the way teachers can dimension their investment. The third role we identify is the Pilot, committed to maintaining control over the course of the session.

In conclusion, we aim at providing teachers with a guide that will enable them to get the most out of the use of serious games, while providing students with a real game experience.

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Exploring Reflective Learning in Digital Game-Based Learning: A User Research Study

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Abstract: Reflective learning has gained popularity as an effective form of education that involves students reflecting on their past experiences to enhance their skills and learning. In recent years, it has been observed that games offer experiential learning and are reflective in nature, making them the ideal medium to integrate reflective learning. With digital games being popular among people of all ages, particularly young adults and children, this study explores the advantages of explicitly incorporating reflective learning into digital game-based learning (GBL) by investigating young adults' perceptions of reflective game design (RGD). Research suggests that digital games implicitly promote reflective learning by encouraging critical thinking, self-awareness, problem-solving skills, and motivation. Additionally, reflective learning provides immediate feedback to students, promoting self-directed learning. Allowing students to reflect on their gaming experiences can make digital games more immersive, leading to deeper learning. The study was conducted in two phases. In the first phase, a survey was administered to 101 young adults between the ages of 18 and 24. The survey aimed to get participants' perceptions and acceptance of games exhibiting reflective features such as heads-up displays, screen maps, message prompts, and performance comparison charts. The results showed that 86.5% of participants accepted the idea of reflective game design, indicating a high level of interest in this approach to learning. In the second phase, fifteen in-depth interviews were conducted to explore further participants' perceptions and acceptance of reflection in games. The thematic analysis of the interviews revealed common trends in using reflective game practices to design a new GBL approach. Participants noted that reflective game design can foster deeper learning, promote problem-solving skills, and enhance learning motivation. This study contributes to developing principles and guidelines for RGD that can assist researchers, educators, and game designers in creating effective educational games. By explicitly incorporating reflective learning into digital GBL, educational games can become more engaging, immersive, and effective in promoting critical thinking, STEM literacy, self-awareness, problem-solving skills, and motivation among students.

Keywords: Reflective learning, Game design, Reflective game design, Learning theories

1. Introduction

In the past decade, digital games have gained recognition as an effective medium for educational purposes and training (Gee, 2004). A survey conducted by the Games and Learning Publishing Council revealed that approximately 55% of 700 teachers incorporated game-based activities into their weekly lesson plans (Takeuchi and Vaala, 2014). The concepts of serious games, Game-Based Learning (GBL), e-learning, and gamification have garnered significant attention in both academic and edutainment domains over the past decade (Martens and Müller, 2017). These concepts often overlap and share common elements, making it challenging to draw a clear distinction between games and artefacts with game elements. Figure 1 depicts the relationship between game-based learning, gamification, and edutainment, highlighting their interconnected nature.

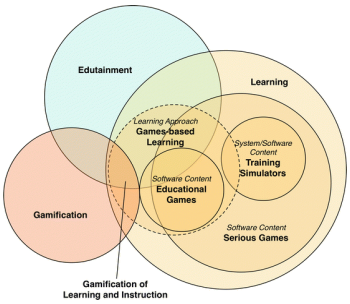

Figure 1: GBL, gamification and edutainment (after (Martens and Müller, 2017)

GBL is an active instructional approach that integrates game characteristics, gamification, learning goals, and pedagogical methods into educational activities, as depicted in Figure 1. According to Prensky (2003), digital GBL can enhance learning experiences by making them engaging and motivating for students. The element of "Play" in GBL is crucial, as it enables learners to connect and interpret their physical and social environments, fostering meaningful learning interactions (Gee, 2004). GBL leverages gaming technologies and techniques to

create immersive and interactive virtual learning environments that promote situated experiential learning (Fotaris and Mastoras, 2019).

Since the last decade, various GBL frameworks have been developed, and learning theories have been incorporated to understand best how games can engage learners in the material. (Kiili, 2005)'s *"Experiential Gaming Model"* focuses on combining experiential learning theory (Kolb, 1984), flow theory and game design to create a new GBL model. It emphasizes that the use of immediate feedback, clear goals and challenges matched to the player's skill level allow for meaningful and engaging learning by experiencing flow. In addition, the Adaptive Digital GBL framework (Tan et al., 2007) has a preliminary focus on the pedagogical elements, psychological needs, cognitive development, and learning behaviours to help understand the learners' learning abilities so that the game can be tailored towards the target group.

Moreover, learning theorists have accepted reflective practice as a well-established learning method since the start of this century (Reynolds, 2011). Reflective learning is a form of education in which student reflects upon their experiences to learn and improve their skills. In this era, where digital games are already accepted as an excellent medium of education, learning theories are being integrated into game-based learning (GBL).

1.1 Learning Theories in Game Design

In game design, learning theories like behaviourism, constructivism, and cognitive theory serve as frameworks for enhancing learning experiences. By integrating these theories, educators and game developers have the opportunity to create educational games that are both immersive and effective in facilitating learning (Dondlinger, 2007). In learning theories, reflective learning is now integral to effective learning. In literature, different models such as Gibb's reflective cycle (Gibbs and Unit, 1988), and the experiential learning model (Kolb, 1984) have incorporated reflection into the learning process. Out of them, the experiential learning model (Kolb, 1984) implementation is closely aligned with the game experience (Shaheen et al., 2022). In addition, game features also provide in-action and on-action reflection. To understand the concepts deeply, the following section explains the experiential learning model (Kolb, 1984) and the in-action-on-action reflection (Schon, 1983).

1.2 Reflective Learning in Game

The researchers, educators and instructional designers are working on incorporating reflective practices into a learning environment (Fleck and Fitzpatrick, 2010, Villareale et al., 2020). Sengers et al. (2005) stressed the importance of reflective practices in game design and came up with the term *"Reflective Game Design"* for the first time. Later, Khaled (2018) published her work explaining the game elements that are suitable to support reflective lining in games and quoted, *"Games are reflection machines"*.

While games inherently possess reflective qualities, only a limited number of existing GBL frameworks incorporate active reflection methods and practices to engage players in the learning process. Among the reviewed literature, Kiili (2005) briefly mentioned the inclusion of reflective feedback in their Experiential Gaming Model; however, their primary focus was on the development of GBL using flow theory. In contrast, the Reflective Game Design (RGD) framework (Shaheen et al., 2022) represents a more recent and iterative model that emphasizes the enhancement of learning through reflective observation and authentic feedback. Reflective feedback holds a central position within this framework, as depicted in Figure 2, enabling the integration of reflective learning elements throughout each stage using experiential learning methods (Kolb, 1984). In the RGD framework, learning in each cycle will be measured by the formative assessment, and consequently, learning results will be used on the next cycle.

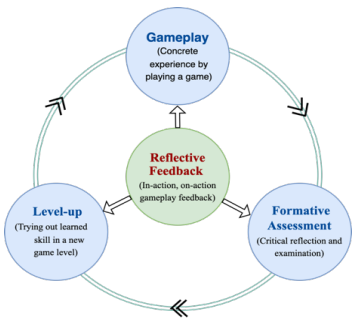

Figure 2: RGD designed Framework (Shaheen et al., 2022)

Moreover, a systematic review of using reflective design features in game-based learning (Shaheen et al., 2021) concluded that reflective design features in GBL improve the learning process, i.e. 1) process displays and prompts improve understanding, 2) social discourse enhances user experience among players with active engagement, 3) process models validate users' learning, yielding learning confidence, and 4) other reflective features such as reflective modes lead to improve critical thinking, problem-solving and retention rate. There is enough evidence of positive outcomes of incorporating reflective practices into GBL. In GBL, games can provide concrete experience with learning reflection in action and reflection on action in the form of Heads up Displays (HUDs), progress bars, visual breadcrumbs, and leader-boards. It is intriguing to research incorporating reflective learning techniques into GBL and their impact on learning.

1.3 Study Objectives

This ongoing research aims to involve the target audience in a design process, and this preliminary study primarily focused on the following objective:

- Investigate the promotion of reflective learning through digital games.
- Assess the acceptance and interest in reflective game design.
- Explore participants' perceptions of reflection in games.
- Identify the benefits of reflective game design.
- Contribute to the development of principles and guidelines.

Hence, the objective of this study is to integrate reflective learning into digital Game-Based Learning (GBL) while providing evidence of its increasing advantages. The subsequent sections of this paper are organized as follows: Section 2 provides a comprehensive discussion of the methodology employed and the details of data collection, Section 3 presents the findings from the User Research, and Section 4 concludes the paper, highlighting avenues for future research.

2. Methodology

The study employs a combination of quantitative and qualitative methodologies, with careful alignment of strategies to the research questions and overall objectives of the investigation. Therefore, the *pragmatic paradigm* (Mackenzie and Knipe, 2006) is a suitable research paradigm for conducting research design. This study aligns with the *"Human Centred Design approach"* (ISO 9241-210:2019, 2019) which underscores the critical involvement of users in every stage of the iterative design process, including design development, evaluation, and refinement. Accordingly, the following methods were employed to facilitate the research process:

- A user survey to know the target audience; the structure of the user survey consisted of 12 sets of questionnaires about general gaming habits to collect quantitative data of
    - Target audience gaming habits.
    - Target audience knowledge of serious games.
    - Target audience understanding of reflection in games.
- Semi-structured interviews were designed to collect qualitative nature of data. The following are the learning goals of the user interview:
    - To understand participants' knowledge regarding games and *"serious games".*
    - To know participants' understanding of reflection and whether they can relate reflection with games.

2.1 Recruitment

The study recruited participants from the target audience of young adults aged 18-24, specifically targeting undergraduate students at the University of Brighton, social forums, and online gaming communities. Recruitment efforts included email invitations to students and the distribution of advertisement flyers within the university and on social media platforms. Ethical considerations were diligently addressed, and ethical approval was sought from the Brighton Research Ethics Application Manager (BREAM) to ensure the appropriate handling of human subjects in the study.

For preliminary user research, this study chose participants with experience playing games to avoid diversity. The designed recruitment survey has a screening question leading to categorising participants based on whether they like to play games or not.

2.2 Data Collection

Data collection in this research adhered to strict anonymization procedures. During interviews and group sessions, no personal or confidential inquiries were made. Participants were provided with a consent form containing an information sheet, which they were required to read and sign. They were explicitly informed about the voluntary nature of their participation. The data collection process consisted of two phases:

2.2.1 A user survey

As the initial effort to engage the audience in reflective learning through games, the study adopted a sequential approach, commencing with an exploration of general gaming habits and gradually introducing the concept of reflective learning to the target audience. The purpose of Survey (Shaheen, 2022) was to keep this survey simple and friendly to get users' true interests. The survey consisted of three components, 1) general gaming habits, such as what type of games they usually play; 2) Participants' knowledge of serious games; 3) How they perceive the idea of reflection through games.

Each question has one open-ended optional response to collect the free thoughts of participants. It was observed that the target audience might not understand the concepts; hence, straightforward explanations were provided for their clarity. The survey was built and distributed over the JIS online survey provided by the University of Brighton.

2.2.2 A semi-structured interview

A comprehensive data collection approach involving semi-structured interviews to obtain detailed and in-depth insights. The interviews were carefully conducted, with a duration ranging between 30 to 40 minutes. The interview process was based on a friendly discussion atmosphere, aiming to establish a comfortable environment that encouraged participants to openly share their perspectives and experiences. The survey findings set the groundwork for the interviews and provided important pointers to discuss with participants in a one-to-one interview. Therefore, the interview script and questions were modified to fit identified pointers.

The semi-structured interview was divided into three categories i.e., 1) Warm-up questions with participants' gaming habits and likeness; 2) Serious games and GBL; and 3) Reflection through games.

The email invitation with the consent form was sent to the 39 participants who signed up for the one-to-one interview, and 15 participants appeared for the interview. Interviews were led to triangulate a preliminary interpretation of the user survey's observations and examine the participants' perception of learning through reflection by games from June 2022 to August 2022. The interviews were conducted online over MS Team, Zoom, and Google Meet according to the participant's preference to overcome geographical and temporal limitations. All interview discussions were transcribed for further analysis using the qualitative analysis tool NVivo. Initially, transcriptions were coded by structure, allowing interviews to be conducted until *"category saturation"* was achieved (Strauss and Corbin, 1990). Hence, data collection stopped when no new codes were developed during the analysis (Baker and Edwards, 2017).

The researcher initiated the semi-structured interview with the research introduction and warm-up questions such as, "What type of games do you like to play?" with a possible follow-up question, "How long do you usually play games every week?" to make participants comfortable. Each question was designed to have a few follow-up questions to carry out a natural discussion. It was ensured that user participation would be friendly to know their genuine opinions and maintain reflexivity.

3. User Research Findings

3.1 Gaming Habit Survey

During the initial distribution of the survey, a total of 100 responses were obtained. Out of these, 92 responses successfully passed the first screening question, which inquired about participants' engagement in gaming. These 92 responses were deemed suitable for further analysis. The quantitative analysis of the Gaming Habit Survey can be divided into three distinct parts for systematic examination and interpretation.

- Regarding the general gaming habits of the target audience, it was observed that participants typically engage in gaming activities on both PC and mobile platforms, dedicating approximately 1 to 5 hours per week to gaming. The most frequently played game genres were identified as First-Person Shooting (FPS) games, including popular titles such as Call of Duty, and Counterstrike, as well as casual games like Candy Crush and various life/farming/building games (e.g., Stardew Valley.).

Findings from the survey indicated that 44.9% of research participants reported a preference for playing games alone, while 28.1% preferred playing with friends, and 27% expressed a desire to play either with friends or by themselves. Interestingly, a significant portion of participants (55.1%) expressed their interest in gaming due to the mental challenges it presents (as depicted in Figure 3), with realism/graphics ranking as the second most influential factor driving participants' attention.

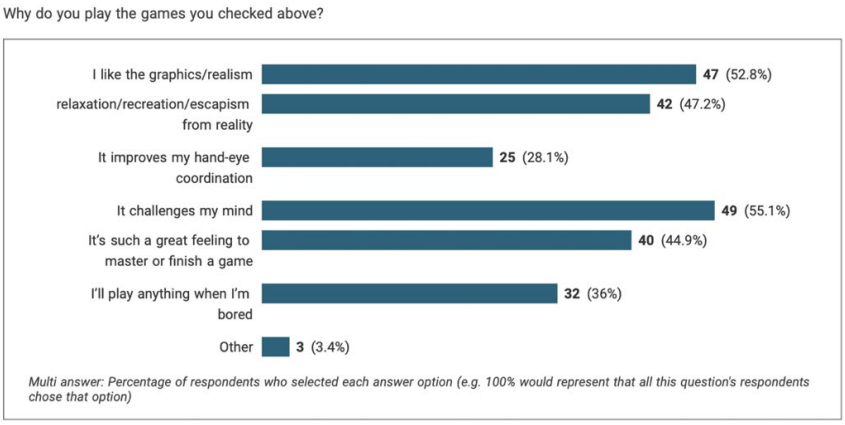

Figure 3: Histogram depicting the element of game engagement in young adults

- Despite the extensive research conducted in the field of serious games and game-based learning (GBL), the survey findings indicate that only a modest proportion of participants, namely 27%, possess knowledge regarding GBL and serious games (refer to Figure 4). Notably, respondents provided additional categories of games, including *"Cyber Security Escape Room"* and one participant highlighted the benefits of serious games, specifically mentioning the enhancement of reflexes, the stimulation of cognitive processes leading to novel ideation, and the acquisition of problem-solving skills.

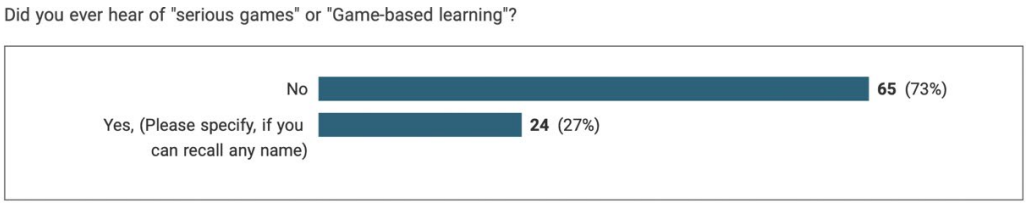

Figure 4: Histogram depicting the knowledge of GBL and serious games in young adults

- The third component of this survey focused on examining the target audience's perception and acceptance of the concept of reflection through games, reflective game features, and reflective learning. Following the clarification of these terms, participants were asked whether they deemed games suitable for facilitating reflective learning. The survey garnered a substantial positive response of 86.5% (as depicted in Figure 5). Subsequently, participants were queried about their observations concerning game elements that exemplify reflection. According to survey responses (shown in Figure 6), Heads-Up Displays (HUDs), such as on-screen scores, maps displaying player location, and progress bars, were highly regarded as practical game elements supporting reflection and reflective learning. The social collaboration received a significant response rate of 60.7%, with multiplayer games being the most prevalent platform for social discourse. Additionally, most participants recognized the significance of a "Process Model" that enables the comparison of players' strategies as a valuable contributor to reflective learning. The remaining options also yielded noteworthy responses, contributing to a comprehensive understanding of the participants' viewpoints. The other option gained an insightful response:

"I think the best practice which compels player for reflective behaviour is giving him loss/punishment over his mistakes. Just the way it is in real life. Humans learn from their mistakes. Mistakes that gave them a loss".

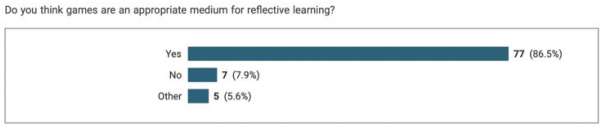

Figure 5: Histogram depicting the acceptance rate of games as an appropriate medium of reflective learning

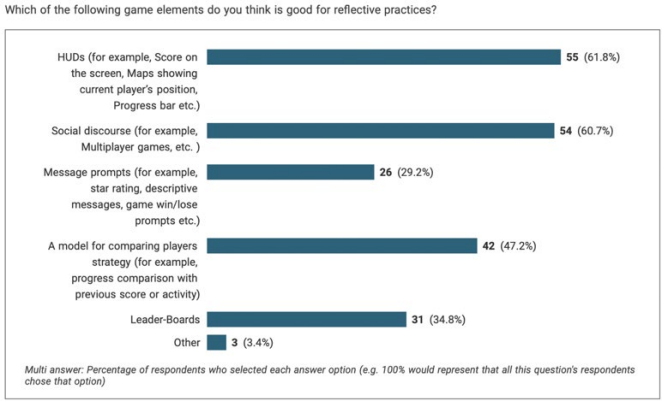

Figure 6: Histogram of the acceptance rate of games as an appropriate medium of reflective learning

3.2 User Interviews Analysis

The qualitative analysis of semi-structured transcription can be categorised into two parts:

3.2.1 Coded by structure

The interview transcriptions were initially subjected to structure coding, following the methodology proposed by Braun and Clarke Braun and Clarke (2006), using NVivo software. A thorough reading of the transcriptions facilitated the identification of essential sections of text that captured the qualitative richness of the phenomenon under investigation, aligning them with relevant themes or issues in the data and research questions (King, 2004). Memos were diligently recorded to highlight intriguing aspects of the data and emerging impressions that had the potential to form the basis of thematic patterns across the dataset. Subsequently, a word frequency analysis was conducted on the extracted codes to obtain statistical insights into popular games, game genres, current trends, and participants' common interests. From this analysis, it emerged that most participants expressed a preference for playing story-enriched, mentally challenging, strategic, adventure, and puzzle games (as illustrated in Figure 7).

Figure 7: Word Frequency Cloud for Game Type

3.2.2 Reflexive Thematic Analysis:

Following the structured coding of the interview transcriptions, a reflexive thematic analysis (Braun and Clarke, 2020) was performed to identify recurring themes and participants' interests that could inform the decision-making process for preliminary design iterations. The resulting breakdown of the identified themes is presented comprehensively in Table 1.

Table 1: Overview of themes from the analysis

Transcending Theme	Major Themes	Sub Themes
The concept of reflection through games-based learning (GBL)	Popularity of games.	Games provide competitiveness. Games provide mind challenges. Games provide a rich story.
	Game as a medium of learning.	Games can help in learning acceptance. Games can help in learning patience. Games can help in learning awareness and mindfulness. Games can help in learning skills such as strategy building and planning.
	Game features supporting reflection.	Reflection in games. Reflective feedbacks such as process displays, prompt messages, and social discourse.

- Transcending Theme: Analysis suggests that participants' responses were generally in favour of the concept in the discussion about comparing the process of reflection with games. A few participants' responses are quoted below:

"Games make me rethink certain situations. Whenever I leave a certain level unfinished, all the scenarios, keep circling in my mind, and I think about different actions if I would take to pass the level."

"Games help the participant to reflect in real-time to reflect their experience. Reflection in games also has given the freedom to fail, retry and retry."

"Keeping updated, when learning a new vocabulary, when a word stuck in mind and when it eventually pops up in a game or conversation using the ability to revisit this and either uses previous learning or refresh memory."

"On the spot will think of the action, do something well, get killed, tries to reflect on where he went wrong. While waiting to respawn, plan the next actions. (In the death timer)."

"It's actually the message the game rules are giving me that makes me rethink or evaluate my approaches to the game."

"I think it's learning through the experience you gained by failing again and again or by experimenting with different approaches to the problem."

The above quotes imply that the participants accepted the idea of reflection through games, and they quickly understood and could relate the reflective learning process with games.

- Major Themes: Three major themes were identified, and each of these themes comprises several sub-themes: The theme analysis shows that most participants like those games that provide competitiveness, mental challenges, and a rich story. One of the participants said during the interview, *"Most of the time, competitiveness in games derives me from playing".* Another participant said that he would like *"any game with strong responsive mechanics and challenging difficulty".* A few participants talked about the game story as one of the reasons they would remain engaged in the game, *"I love story-enriched games".* The third most repetitive reason given by the participants was "game challenges their mind". One participant said: *"Puzzle games, which challenge my mind. I play till it challenges my mind, and then I switch the* game If it's too easy", and another mentioned, *"Any game with strong responsive mechanics and challenging difficulty".*

"Game as a medium of learning" is identified as a second major theme. The gaming habit survey revealed that most participants are unaware of serious games or GBL; therefore, during the interview, they were asked whether they have learned any learning from games. They listed that games could help in learning acceptance, patience, awareness and mindfulness and other skills such as strategy building and planning. One participant spoke about their experience of games regarding mindfulness and acceptance *"(game)Life is strange;*

accepting that some things you can't (or can) control. Live in the moment and try not to think too much ahead." another participant stated, "*Helped learn patience and planning".* In addition, "*rage quitting"* was another skill learned from playing games with one of the participants.

The third most crucial theme was *"Game features supporting reflection",* Participants agreed that they found games' features reflective in nature. The following two participants' statements support this theme, i.e., *"The games I play are already made on this reflective cycle" and* "I agree, I can relate a game experience with this *reflective* cycle". A few participants talked about the importance of game features such as HUDs and prompt messages; they said, *"It's actually the message the game rules are giving me is what makes me rethink or evaluate my approaches to the game"* a few participants revealed that *"I agree that Audio/Visual feedbacks such as HUDS, display prompts play a vital role in learning", "Leader board - competitive nature motivates you to improve by repeating, Death recap (dependant on the game. e.g., in strategic, RPG based games)",* and *"Helped me to gain an outside perspective and experience. Leader boards, helps understand progress".* Despite reflective feedback importance, one participant pointed out, *"HUDs and GUDs can sometimes be too big and overwhelming on the screen (in mobile games). Only use necessary information. Requires simplicity." and "Sometimes HUDs is a distraction when you have lots to do. Otherwise, they are very helpful".*

4. Discussion

The in-depth analysis of the user research data has yielded intriguing findings, underscoring the significant potential of games as a means of facilitating reflective learning. The outcomes highlight the capacity of games to offer a transformative learning experience characterized by critical thinking, self-awareness, problem-solving skills, and motivation. The data analysis showcases the effectiveness of games in promoting reflective learning, demonstrating their ability to engage learners and encourage deeper levels of comprehension and knowledge acquisition. The most important findings are:

- Among the participants surveyed, the genre of FPS emerged as the most popular category of games. FPS games encompass a wide range of elements, including strategic planning, puzzle-solving, multiplayer interactions, and more. It was of particular interest to explore the factors that contribute to the popularity of this genre. To delve deeper into this aspect, the interview questions were modified to gather detailed insights. The subsequent analysis of the interview data shed light on the key elements that make FPS games appealing, namely engaging puzzle activities, immersive and captivating narratives, strategic game mechanics, and mentally stimulating challenges. These findings provide valuable insights into the preferences and interests of the participants, informing the design and development of future games within the FPS genre. These findings will be incorporated into ongoing research aimed at co-designing a game that integrates reflective learning principles.
- Although 73% of participants were unaware of "Serious games" or "Game-based learning," they reported that digital games facilitated the development of various skills, including acceptance, patience, hand-eye coordination, freedom to explore, mindfulness, and strategic thinking.
- Interestingly, the participants demonstrated agreement regarding the concept of "reflective learning through games," as evidenced in Figure 10. This shared perspective served as a key motivator for the integration of a reflective cycle into the interview script, enabling in-depth discussions on the topic. Notably, a subset of participants expressed a preference for simplistic heads-up displays (HUDs) to facilitate game progress reflection. These individuals perceived complex and cumbersome HUDs as potentially distracting and overwhelming, emphasizing the importance of user-friendly design considerations in promoting effective reflective learning experiences within games.

Based on the user research conducted in this study, it becomes evident that the target audience possesses a comprehensive understanding of reflective learning through games. Despite limited familiarity with terms such as "serious games" or "game-based learning," participants exhibited a highly positive response towards the concept of reflective learning within digital games. Their interviews further revealed valuable insights on improving reflection through game elements, particularly heads-up displays (HUDs). Consequently, this research offers compelling evidence of participants' acceptance of digital games as a superior medium for facilitating reflection. Participants emphasized that games enable them to engage in concrete experiences, reconsider situations, reflect upon them, and make subsequent attempts, a fundamental aspect of the reflective learning process. These findings shed light on the transformative potential of games as educational tools and lay the foundation for the development of innovative and impactful reflective game-based learning approaches.

5. Conclusion and Future Work

The present study investigated the perception of young adults regarding "reflective learning" within a digital game context. Data was collected through a user survey and semi-structured interviews, employing qualitative and quantitative analyses to extract insights into the interests of the target audience. The results consistently indicated that games, even if not explicitly designed as serious games, can effectively facilitate reflective learning. This involves providing users with concrete experiences, encouraging a rethinking of situations, facilitating reflection on experiences, and offering a platform for improvement based on past experiences. These findings will inform the design decisions for creating a game aimed at enhancing self-awareness.

In the future, these designs will serve as the foundation for co-design sessions with participants to develop a game-based learning (GBL) experience supporting *"Reflective Game Design".* The final reflective game design will undergo evaluation, with the results used to establish guidelines and principles for reflective game design.

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Making Legislative Process Understandable: Survey of Parliaments' Serious Games of European Countries

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Abstract: In addition to passing legislation, many parliaments in Europe and around the world engage in educational activities aimed at promoting democracy and explaining the legislative process. Increasingly, these educational activities take the form of serious games. But just how many European parliaments use games, and what do these games involve? This study is a survey of the use of serious games by European national parliaments' visitor centres, based on a questionnaire and web page analysis. Out of the 43 countries surveyed, 25 were found to use some form of games. The study maps the game genres and activities the games contain, as well as the parliaments' rationale for using them and intended target audience.

Keywords: Serious games, Political games, Parliament RPG, Parliamentary simulation

1. Introduction

A cornerstone of any functioning democracy is its citizens' trust in democratic institutions and satisfaction with the democratic process itself. Factors that influence trust in and satisfaction with democracy are manifold and vary depending on cultural and socioeconomic context (Daoust & Nadeau, 2021). Among these, two key predictors are political interest and knowledge. Political interest refers to citizens' willingness to both follow politics and engage in the political process. In a functioning democracy, the higher an individual's political interest is, the more likely they are to be satisfied with democracy itself (Chang, 2017). Political knowledge—citizens' understanding of how democratic institutions work and why—is also a predictor for both citizens' trust in these institutions and willingness to engage with them (Memoli, 2021).

As such, educating citizens about the workings of democracy and raising their interest in the subject are crucial tasks for democratic institutions. This is especially true at a time when populist discourses around the world often promote political cynicism and alienation among the youth (Noack & Eckstein, 2023). Governmental institutions, including parliaments—the "faces" of the democratic process in action—have a major role to play in tackling this issue.

Indeed, governments and parliaments worldwide offer various educational activities, including guided tours, exhibitions, as well as simulations and so-called serious games. Games and simulations are an appealing form of civic education because of their potential to be highly engaging, as well as their ability to dynamically model complex systems (such as the parliamentary process), rendering them easier to understand (Bogost, 2006; Neys & Jansz, 2010). In other words, games can help raise both political interest and knowledge. To what extent and how they are used by political institutions, however, has rarely been examined in a systematic way.

The present study aims to determine how European countries use serious games to introduce their parliaments' work to citizens. It seeks to map the reasons for the games' use, as well as their genres and the activities they involve. In doing so, the paper explores how European parliaments use serious games to bring the governing and legislative process closer to their citizens.

2. Theoretical Overview

Politics and games are interwoven in many ways. First, we often think and talk about politics as if it were a game, often without even realising the language we are using is metaphorical. In media discourse, political agents often become "players" who engage in a "zero-sum game" with clearly determined "winners" and "losers" (Aalberg, Strömbäck, & Vreese, 2011). Moreover, political scientists often model political processes as rule-based "games" involving players with differing goals, and political game theory has evolved into an entire branch within game theory (McCarty & Meirowitz, 2007).

Second, politics can also inform the content of games themselves. This ranges from representations that implicitly reflect the game creators' political views without the game being intended as political (Licari, 2020) to games that are consciously designed as forms of political discourse (Bogost, 2006). The latter category includes government-commissioned propaganda games such as the US' *America's Army* and China's *Glorious Mission* (Sandovar, Braad, Streicher, & Söbke, 2011), games that contribute to grassroots political activism (Wirman &

Jones, 2020) and political resistance (Huang & Liu, 2021), as well as those created by disenfranchised citizens to "let out steam" in the absence of genuine political agency (Serada, 2023; Souri, 2007).

Adjacent to these are digital and non-digital serious games—those designed with a clear educational goal, with the entertainment aspects being secondary—that relate to politics (Dahya, 2009; Neys & Jansz, 2010). A common subcategory of these are games aimed at developing political knowledge and increasing political interest among (young) citizens. These can be designed with schools in mind and integrate with existing political education and civics curricula (Blevins & LeCompte, 2016; Zamora, 2019), or be created by or for cultural and political institutions such as museums (Schaller, 2015) and, most pertinently for this paper, parliaments.

A prominent example of a political serious game is the Youth Parliament: a role-playing game (RPG) in which players take the role of Members of Parliament representing different constituencies, who must through negotiation and debate arrive at decisions that take into account the constituencies' needs and interests. By doing so, the game helps engage teenagers in civic and political life, teach democratic principles and concepts, explain the mechanisms of the legislative process, and build a sense of ownership of democracy (Milliken, 2001; Shephard & Patrikios, 2013; Cowley & Stuart, 2015). This experience is often used as part of civic education (Fuks, 2015; Zamora, 2019).

The Youth Parliament exists in many countries and comes in different forms. In Europe, notable examples include the European Youth Parliament (EYP), the Model European Parliament (MEP), and Parlamentarium. For example, EYP is an international organisation with representatives in over 40 European countries. The role-playing sessions offered by EYP take place at the regional, national, and international levels. Each session has three parts: team building to get to know each other; working in committees to discuss critical European issues; and the general assembly: a standard parliamentary procedure where committees debate the proposed solutions. International events take place three times a year in different European countries, with 200–300 participants from some 40 countries coming together for nine to ten days. EYP coordinators facilitate the role-play activities during the sessions, as well as organise media coverage (EYP, n.d.).

Youth Parliament initiatives have been highly valued by teachers (Moreno-Fernández, Puig-Gutiérrez, & González-Monteagudo, 2018). Some research suggests that they can increase not only participants' political knowledge (Zamora, 2019; Cruz-Martínez, Sainz, & Sánchez, 2022), but also their confidence in democratic institutions (Fuks & Casalecchi, 2012), and that they can even directly lead to civic initiatives by the youth (Shephard & Patrikios, 2013). At the same time, changing participants' core values and political beliefs, if they are at odds with democratic governance, is often beyond what a Youth Parliament can accomplish (Fuks, 2015). Youth Parliament initiatives have also been criticised for not doing enough to engage rural youth (Trivelli & Morel, 2021) and under-representing marginalised communities and issues relevant to them (Turkie, 2009). These limitations are not inherent to the Youth Parliament model, but rather stem from how specific implementations are designed and framed: their shortcomings often reflect the organisers' failure to meaningfully and genuinely engage their participants and partners (Elliott, 2021).

Before we can systematically address and rectify these shortcomings, it is important to map the existing use of political serious games by parliaments. The present study aims to do just that, focusing on the games used by national parliaments in Europe. These are not limited to variations on the Youth Parliament format, but also include other serious games employed by the parliaments for educational purposes.

3. Methodology

The main methodology of this study is a survey of European national parliaments regarding their use of serious games for civic education. A qualitative questionnaire was used to collect data from European Parliament visiting centre representatives. Additional information was collected through a study of the parliaments' web pages. Triangulation was used to ensure the study's validity: data was collected from two sources by two researchers.

The parliaments' web pages were briefly studied at the start of the project, and the findings were used to create the questionnaire, which was employed between December 12, 2022, and February 10, 2023. After a preliminary study of questionnaire results, a second iteration of analysing the parliaments' web pages was conducted in April 2023. Additional online sources were consulted when more information was required.

3.1 Population and Sample

The population of this study are the parliaments of European countries. The question of how many countries are there in Europe has multiple possible answers. According to the United Nations (United Nations, n.d.), the number of European countries is 44 (this excludes Armenia, Azerbaijan, Georgia, and Turkey, as well as

autonomous territories such as the Åland Islands, Gibraltar, and the Vatican). Russia and Belarus were excluded from the study, due to being authoritarian states whose parliaments do not conform to democratic principles (as evidenced, for example, by the two countries occupying the two last places in Europe in both the 2022 Economist Democracy Index and the 2022 Bertelsmann Transformation Index). Kosovo was included, despite not being a UN Member State, due to being a new state in the centre of Europe recognized by most European nations. The final population size is thus the parliaments of 43 European countries.

An invitation to participate in a survey on the use of serious games by parliaments was sent out to each parliament's representatives via the International Forum of Parliament Visitor Centers. This forum is a network of national parliaments that aims to foster cooperation between visitor centres to exchange the best educational practices (IFPVC, 2016). (This is because serious games and other educational activities typically fall under the domain of visitor centres rather than the parliaments' legislative departments.) In total, 11 responses were collected from European countries, with a further two—which were not used in the present study—coming from non-European nations. Parliaments in different countries have different structures (e.g., some consist of one chamber while others are bicameral) and are referred to by different names, such as Assembly, Council, House of Representatives, and so on. For the sake of simplicity, in this article, they all are referred to as parliaments.

As all 43 European parliaments were sent an invitation to the survey, the total of 11 responses makes for a response rate of 25.6%. Because of the low response rate, additional data collection through the parliaments' websites was required, and the websites for each of the 43 parliaments were analysed.

3.2 Questionnaire

The questionnaire focused on qualitative data and consisted of the following open-ended questions:

- Does your parliament use educational games to introduce the legislation process or other aspects of governance or democracy?
- If yes, can you provide the name of the game and a reference (link, PDF, etc.) to find more information about it (description, target audience, etc.)?
- How frequently is the game used? (Where possible, please share the number of users)
- What is the reason behind the choice/implementation of such a game?
- Do you or the users have any feedback about the game?

The questions were sent out by email and in a text document format to the parliaments' visitor centres. This approach was chosen to give research participants more freedom to choose the level of detail of their answers. In some cases, this led to the detailed responses outlining the different games used by a parliament's visiting centres. In addition, some answers included supplemental materials in the format of presentations, videos, web pages or screenshots.

3.3 Study of web Pages

A study of European national parliaments' web pages was conducted to find additional evidence about the use of serious games. Each national parliament's home page was visited and searched for relevant information. Some web pages made the search easy because they were clearly structured (site maps were a particularly helpful feature) and translated into English; others were more challenging to navigate, particularly when no English version was available (for these, Google Translate was used). Evidence of game use was primarily found in such sections as Education (sometimes named Library or Visits), Public Relations (the part aimed at citizens), and About the Parliament (or How the Parliament Works, etc.). When looking through these sections yielded no evidence, the web site's search functionality was used, with search terms including "game", "simulation", and "youth". It remains a possibility that some of the available evidence was not uncovered due to translation issues and terminological differences.

3.4 Analysis of Games

When evidence of game use was discovered on the parliaments' web pages or submitted by the survey respondents, the game description was analysed. When needed, Google Translate was used. Web-based games were played, and paper-based game materials were reviewed.

3.5 Data Analysis

Open coding was used to analyse the survey results and findings from the parliaments' web pages. The following categories and codes were generated and used:

- Game format: physical (local), digital: local, online, interactive video.
- Game genre: colouring book, puzzle, quiz, interactive exhibition, interactive guided tour, guided tour with RPG elements, short RPG (1–3 hours), medium RPG (0.5–1 days), long RPG (two days to one year), (single-player) simulation.
- Game activities and topics: walking tour, the legislative process, creating a law, collecting resources, the division between parties, discussion, speech, debate, voting, printing the law, parliament premises, MEPs involved, speaker or president involved, committees, plenary assembly, collecting votes, competition, elections, government formation, political scandal, newspaper headlines.
- Target group: children (subdivided into 5–9 and 10 –12), teenagers (13–16 and 17–19), adults (>19)
- Number of players per session: 1; 2–9; 10–35; 100–200.
- Playing frequency: 2–4 x D (2 or more times a day), 1 x D (once a day), 2–4 x W (2 or more times per week), 1 x W (once a week), 2 x M (2 times per month), 1 x Y (once a year).
- Serious objectives: entertain visitors, teach democratic processes, connect students and politicians, teach legislative process, arouse interest in politics, promote critical thinking, and increase involvement and motivation.

Based on the findings, data tables were created. Data analysis was conducted in two iterations. First, the responses to the survey were analysed based on all the questions. Second, an additional study of the parliaments' web pages focused on game genres and their activities. The results are available here:

https://docs.google.com/spreadsheets/d/1z-zS090nCu6W4qO5IA-U5BwAhmhN-alA0S4dK2VgwX8/edit?usp=sharing.

4. Results

4.1 How Many European Parliaments Use Games?

Out of the 11 European parliaments that responded to the questionnaire, ten (91%) reported using educational games to introduce the legislation process or other aspects of governance or democracy. Based on the additional analysis of the parliaments' web pages, 25 countries out of 43 (58.1%) use games in some form. While the remaining 18 countries' parliaments appear to not use games, it is possible that some of the games were not discovered due to the language barrier.

Some parliaments (for example, Austria, Germany, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Norway, Serbia, and the United Kingdom) use multiple games. Most of the parliaments offer physical, on-site games, where the play experience is designed as part of the parliament visit. Some parliaments have made their games available online (Lithuania, Norway, and the UK).

Altogether, 40 different games were identified. Outside of the sample, the parliaments of Brazil and the USA also reported using political serious games.

Table 1: Games used by the parliaments of European countries

#	Country	Game
1	Albania	NO
2	Andorra	Short RPG: Consell General dels Joves – General Council of Youth
3	Austria	Interactive Exhibition: Demokratikum; Puzzle: Doppelmoppel and Deine Woche als PolitikerIn; Quizzes: Bildersuchrätsel, Themen; RPG: Youth Parliament
4	Belgium	Interactive guided tour: Objectif loi
5	Bosnia and Herzegovina	NO
6	Bulgaria	NO
7	Croatia	NO
8	Czech Republic	Short RPG: Parliamentary Simulation
9	Cyprus	NO
10	Denmark	Guided tour + RPG: Politician for a Day

#	Country	Game
11	Estonia	Long RPG: Noorte Riigikogu
12	Finland	NO (earlier game, Lainsäätäjät, currently not available)
13	France	Puzzle: Senat Junior
14	Germany	Guided tour + RPG: Rollenspiel, Medium RPG: Planspiel
15	Greece	NO
16	Hungary	Medium RPG: The democracy game; Long RPG: Model Parliament
17	Iceland	Tour + RPG: The Dragon at the Parliament; Short RPG: Skolathing
18	Ireland	Short RPG: Politics and Society live experiences
19	Italy	NO (earlier game, Il Parlamento dei bambini, no longer available)
20	Kosovo	Interactive exhibition: Once Upon a Time and Never Again
21	Latvia	Interactive tour: Meet the Saeima; Long RPG: Jauniešu Saeima – Youth Parliament
22	Liechtenstein	NO
23	Lithuania	Short RPG: How is the law drawn up?; Quiz: Seimas Vaikams
24	Luxembourg	Short RPG: #MengChamber; Simulation: DemocraCity
25	Macedonia	Short RPG: Имам став! - In my opinion!
26	Malta	NO
27	Moldova	NO
28	Monaco	Long RPG: National Youth Council
29	Montenegro	Short RPG: Parliament Simulation
30	Netherlands	Puzzles and quizzes: Third Chamber
31	Norway	Short RPGs: Demo, The Choice is Yours, The Government Negotiations
32	Poland	Unclear genre: Mlody Obywatel
33	Portugal	Long RPG: Parlamento Dos Joventos – Young People's Parliament
34	Romania	NO
35	San Marino	NO
36	Serbia	Short RPG: Simulations of National Assembly sessions; Uncleear genre: Your Vote
37	Slovakia	NO
38	Slovenia	NO
39	Spain	NO
40	Sweden	Guided tour + RPG: Demokrativerkstaden – Democracy Workshop
41	Switzerland	Short RPG: Mon point de vue – My point of view
42	Ukraine	NO
43	United Kingdom	Simulation: MP for a Week; Guided tour + RPG: Tours and workshops

4.2 Reasons for Using Serious Games

The parliaments' motivation for implementing serious games varies. The most frequently cited reasons are (most popular first):

- Introduce the work of the parliament;
- Teach democracy and increase civic awareness;
- Introduce the legislative process;

- Make visitors feel like valuable members of society (civic involvement);
- Entertain visitors (make their visit attractive and fun);
- Connect students and politicians;
- Reduce the barriers (increase the interest) to teaching democracy and parliamentarism;
- Develop critical thinking.

One of the respondents concisely explained some of the key reasons as fellows:

> *For many people, democracy and parliamentarism are abstract and complex and not an interesting topic. These games should help to break down the barriers and invite the visitors to playfully explore the different issues the parliament has to deal with. Second, visitors should get the feeling of being a valuable part of the society and understand it.*

These serious goals largely align with the broader goals of civic education.

4.3 Game Genres

The parliaments' educational games belong to the following genre categories:

- Quiz (3: Austria, Lithuania, and the Netherlands);
- Puzzle (3: Austria, France, and the Netherlands);
- Interactive exhibition (2: Austria and Kosovo);
- Interactive guided tour (2: Belgium and Latvia);
- Guided tour with short RPG (5: Denmark, Germany, Iceland, Sweden, and the UK);
- Short RPG (13: Andorra, Czech Republic, Iceland, Ireland, Lithuania, Luxembourg, Macedonia, Montenegro, Norway x 3 games, Serbia, Switzerland);
- Medium RPG (2: Germany and Hungary);
- Long RPG (6: Austria, Estonia, Hungary, Latvia, Monaco, and Portugal);
- Simulation (2: Luxembourg and the UK);
- In two cases, the genre is unclear.

The most frequently mentioned game genre is a short (1–2 hours long) RPG provided as part of a guided tour of the parliament (mentioned five times) or as a stand-alone activity (mentioned 13 times). The second most mentioned game genre is a long RPG, lasting between two days and a year (mentioned six times). Taken together, short, medium and long RPGs account for 23 games out of 40 (52.5%). Interactive quizzes and puzzles (typically, physical games that can be played at the visitor centres) were mentioned three times each. The following section discusses the activities that games in different genres contain.

4.4 Activities in Parliament Games

The **puzzles** are typically physical games that can be played at the visiting centres. For example, the Austrian Parliament Visitor Centre offers a puzzle aimed at 5–8 year olds where players have to design a city square. The goal of the game is to experience group discussion and decision-making. In addition, some parliaments offer simple online puzzles (such as memory games).

Most parliaments offer **guided tours**. Some have added playful interactive activities to increase visitors' engagement. For example, the Austrian parliament issues tour participants with "passports" that they can use to collect stamps (badges) from different areas of the parliament. In other countries (Belgium, Denmark, Iceland), the tour includes a short RPG-like workshop where the participants can propose their own law, participate in a parliamentary discussion, and vote on the proposed legislation. Participants can even have an accepted law printed out as a "document" to take home as a souvenir. The typical duration of a guided tour with such interactive activities is 1.5–2 hours, and the group size is 15–30 people. Such guided tours are mainly provided for children and teenagers. Some parliaments (such as Austria) also offer **virtual guided tours** where users can enter parliament members' working rooms in an online environment.

Many parliaments introduce their work and the legislative process through a short **role-playing game**. In several cases, this game takes place in specially designed rooms that imitate the setting of a real parliament. This arrangement makes it possible to play the game several times a day (for example, in Norway, twice daily). Sometimes, the game takes place on the parliament's actual premises. This approach limits how often the game can be played (for example, twice a month in Czechia and 85 times per year in Lithuania). A typical game session proceeds as follows:

- Players are divided into 4–6 political parties and asked to read their parties' manifestos.
- A critical political issue is introduced by the game facilitators or raised by the players themselves. Players are asked to propose a new law or amendments to an existing law to address the issue.
- Details of the new law are discussed in committee groups, presented (players have to select spokespersons and give speeches), and voted upon during the plenary sessions.
- The feedback on the game outcome is delivered as the voice of the citizens (fictional characters in the game).

Some games involve real parliament speakers (for example, in Iceland) or actual parliament members (for example, in Macedonia and Switzerland). In some games, players are asked to form a government (e.g., in Norway) or to collect signatures to start a new law (e.g., in Lithuania). The typical duration of a short RPG is 1–3 hours, and the group size is 10–35 players. Such games are mostly provided for teenagers. Some parliaments offer a similar game but of a longer duration. For example, in Hungary, the parliament RPG lasts one day, and in Germany, 6 hours.

Some parliaments provide a more extensive RPG experience called the Youth Parliament (not to be confused with the European Youth Parliament, which is coordinated by an international NGO). This game has similar features to a short RPG, but lasts more than one day, sometimes a whole week (Belgium), and takes place on the parliament's actual premises, using plenary and committee rooms when there are no parliament activities (e.g., weekends). Due to the limited availability of the facilities, bigger RPGs are usually played once per year. The number of players is limited by the size of the plenary room (e.g., 100–150 in Belgium). This longer format usually also includes pre-visit activities at school and post-visit activities. Sometimes (e.g., in Monaco), the long game largely takes place outside of the parliament, and visiting the actual parliament is a culmination at the end of a one year long experience.

While most of the games are collaborative in nature and focus on reaching a compromise through discussion, some games do emphasise competition between political parties during the debate (e.g., in Macedonia and Switzerland). In these competitive games, the players debate each other on a chosen topic, after which the strength of their arguments is assigned a score by a jury of actual parliament members.

5. Discussion

A majority (58.14%) of European national parliaments use serious games to introduce the parliament's work or educate citizens about parliamentarism and democracy. In some countries, parliamentary games are offered by third parties rather than the parliaments themselves; these were only included in the study if they were mentioned on the respective parliament's website (for example, this was the case in Estonia). Other countries mentioned an interest in using serious games in the future. This shows that parliaments and governments more broadly have understood both the need for civic education and games' potential for making such education engaging and meaningful.

In two cases, Finland and Italy, serious games were used in the past but are no longer available. In the case of Poland, the web game was created using Adobe Flash, which contemporary browsers no longer support. This points to the challenges presented by technological obsolescence, as well as to the importance of considering future sustainability in design and implementation of serious games.

In terms of genre, role-playing games are the most common. Although more challenging to design compared to such genres as quizzes and puzzles, it appears that the RPG is deemed the most suitable genre for civic education, as it allows to directly engage players in activities that mirror the core nature of parliamentary work: forming groups, having discussions, and making joint decisions. Another core characteristic of RPGs is developing the individual character (for example, acquiring new skills and improving existing abilities). There is no evidence that RPGs used by parliaments incorporate this characteristic in a prominent way; this is likely because it is less relevant to the collaborative nature of the legislative process they seek to represent. However, actually incorporating character (or perhaps group) development mechanics could in fact be useful both in terms of meeting player expectations (young players experienced with RPGs may expect this feature) and communicating player progression, providing an incentive for continued play, especially in longer RPGs.

Most of the games offered by the parliaments are physical, on-site games: players must visit the parliament in person and play the game in specially designed rooms. This affords more immediate social interaction between the players and offers a more situated experience, but it also limits the accessibility of the game, due to requiring travelling and, often, pre-booking. Offering similar experiences that are available online or as a downloadable

game is something few parliaments currently do, but it can dramatically broaden the games' reach and go some way towards addressing the criticism of parliamentary games excluding rural communities and marginalised groups.

6. Conclusion

The evidence collected during the study suggests that serious games have become a popular tool for European parliaments to promote democracy and educate the youth and citizens more broadly. Most of the European parliaments already use a serious game—or, in some cases, several—and the number is likely to increase. Role-playing games are by far the most popular genre, although analysing how many role-playing game mechanics they actually contain is beyond the scope of this study. Neither has the study established how many players each of the games has reached.

A direction for future research would be to investigate the player experience of each game. How engaging do players find the games (and how does reported engagement correlate with specific game genres or activities)? To what extent does playing the games stimulate political interest and help develop political knowledge? How do teachers perceive the games' utility for their classes? Are any cultural differences between the different countries' games evident in the player reception or the game design itself? These would be useful questions for a closer analysis of the games.

Another direction that would be useful to investigate relates to the games' accessibility and sustainability. This covers both how the games can be maintained to future-proof them against obsolescence, and how to ensure that the games reach a broad and diverse player audience.

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Introducing Game Jams for Ecology and Citizenship Education in High School Classes

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Abstract: This paper deals with the preliminary results of some applied game jam events integrated with the Citizenship and Civic education project in some Italian high schools. In Italy GBL is not systematically used as a didactic tool, especially in secondary school and game jamming is not well known nor used. A set of specifically designed game jam events called (EcoGJ - the game jam for ecology) were implemented in Italy during the 2022/2023 school year. The game jam format was designed to promote the discourse about climate change and ecosystems, and implemented to demonstrate how a more student-centred didactic approach can be used at school to foster collaboration and team working skills. Students in the 15-16 target age from different high schools have been involved in the EcoGJ format. Outcomes have been recorded with a survey and with on-field notes. Preliminary results show as game jams had a positive impact on students, encouraging them to use critical thinking and team working as well as activating them in discussing ecology and climate change issues. Notwithstanding, some critical points emerged both for students in terms of engagement and knowledge. It seems that game jams can be a valid working method to teach and learn new skills, as well as increase students' self-confidence and their desire to learn more about complex issues such as climate change. Further explorations are needed to find the most adequate way to introduce game jamming in high school and the best format to use these events in the most effective way to foster students' engagement in learning and to help them in deepening their scientific-based knowledge in ecology and climate change.

Keywords: Game jam, Game-based learning, Ecology, Education, High school

1. Introduction

Games hold the potential of promoting people learning because they are motivational, are drill and practice, are content mastery, and they can promote 21st-century competencies (Jan, et al., 2015, Mingfong and Gaydos, 2016). Embedding games as part of the lessons is the pillar of the Game-Based Learning (GBL) teaching approach. In GBL, games chosen by teachers for specific educational purposes, are played to help students in reaching defined learning outcomes in terms of disciplinary contents or skills or both (Shaffer et al., 2005). This didactic approach has constantly emerged and been implemented as a student-centred learning technique (Plass et al., 2015) highly effective at different school grades and for a great number of disciplines and skills. Considering the principle of "learning by doing" as expressed by Dewey and considering the gaming world inhabited by players and by game developers, other uses of games can be included in the GBL approach such as game development and game jamming. This paper it is used the definition of game jam as described by Kultima (2015) as "*an accelerated opportunistic game creation event where a game is created in a relatively short time frame exploring given design constraints, with the end results shared publicly.*" From an education perspective, game jam can be considered as an expression of a broader constructionist learning paradigm, in which learning happens through creating concrete artifacts (Papert and Harel, 1991; Kafai and Burke, 2015) fostering learning in multiple areas (Whitton, 2018). As indicated by Meriläinen et al. (2020), three are the specific themes explored by game jam learning: game development skills; STEM/STEAM skills; personal and interpersonal skills including work-related skills. Several papers explicitly discuss the potential of game jams in promoting STEM or STEAM learning (Fowler et al., 2016, Pollock, Murray, and Yeager, 2017), concluding that game jams have the potential to successfully engage young learners in scientific disciplines, to promote the deep learning of scientific contents, and to increase participation in both STEM subjects and careers. Furthermore, a game jam is an effective tool for student inclusion and is a peer-to-peer education experience in which each participant can contribute also using creativity and a wide set of personal skills usually underused in the daily school context. Environmental and Sustainability Education (ESE) is STEM-based but needs additional skills, like problem-solving, problem analysis, system thinking, and cooperation abilities, to be efficiently learned and applied in daily life and from a future perspective. Finally, game jam can be helpful in encouraging students to deal with sustainability and climate change issues, just as it can be effective in fostering the new and complex skills requested to deal with future environmental and global challenges. In Italy, the GBL approach is debated at the academic level but not systematically implemented at school as part of the didactic approaches and as part of pre-service and in-service teachers' education (Vezzoli Y., and Tovazzi A., 2018). Generally, in Italy at primary school, it is effectively used to boost learning of some contents and to facilitate life skills emergence in students. At the middle school level, GBL tends to be used less in disciplinary content learning, but it remains useful to exercise skills. GBL is even less

used at the high school level and the university level. In the last years, some experiences have been conducted at primary and middle school levels in digital environments (Bottino et al., 2009, Cecchinato et al. 2019) mainly for language and math learning, logical competencies, or engagement (Benigno et al., 2010, Bottino et al., 2014, Cinganotto L., 2019,). Nonetheless, while this research is proceeding, a complete review of the state of the art of GBL implementation in Italy is missing such as a comprehensive study of the reasons why it is not used from teachers' perspective. If GBL is not yet well rooted in Italian schools, less is done with game jamming which is mostly unknown to the teachers, and it is a new concept also at the academic level. Nevertheless, considering other studies occurring in the European scenario (Aurava and Marilanen, 2020, Nousianen et al., 2018) it can be assumed that the reason for the resistance to the GBL and game jamming can be resumed in some points: lack of knowledge of GBL principles and game jamming as education tools, difficulties in finding adequate spaces in schools, the time needed to organize and implement a game jam session, inflexibility of curricula and educational outputs required by the Italian school system for each subject. On the other hand, the tentative to produce some change in the Italian school is in place and a good number of courses for in-service teachers are being implemented together with an attempt to strengthen the network between school and academic research to foster innovation and reach the European educational goal for the future. In this tight opening, the first research line in collaboration with the school is growing, and this research is part of this new line.

The overall objective of this research is to understand what educational outputs can have and how game jamming can be applied in ESE at the high school level. To achieve the overall objective, some sub-questions came from the main one. In this paper the focus is on the specific theme of the educational outputs derived from the main research purpose, split into two sub-questions: a) What skills game jamming can boost in students, and in what measure this process is conscious in students, and b) How the level of engagement in ecology can be influenced by a dedicated game jam event. To offer a preliminary answer to these questions, the design of the game jam format and the measured educational outcomes of a first trial of an event held over three days in January 2023 at Liceo Scientifico "Leonardo da Vinci" in Trento (Northeast of Italy) are presented. It is first presented the applied game jam's format, the educational aims, and the placement in the curriculum, then preliminary results in terms of skills and learning outcomes are discussed, based on the qualitative content analysis of questionnaires filled in at the end of the game jams and integrated with the fieldnotes and observations done during the sessions.

2. Research Questions

In European schools are in place significant experiences to introduce game jamming as a didactic approach, particularly in STEM disciplines and ESE. However, this method is not well known or applied in Italy and less at the high school level. To contribute to the implementation of game jamming at the high school level particularly in ESE in Italian schools, the whole research aims at exploring how to implement game jams. In this paper, two main sub-questions are investigated:

- What skills can a game jamming boost in students?
- Scientific knowledge in ecology can be improved by a dedicated game jam event.

3. Methods and Format

In the school year 2022-2023 an experimental educational format, based on game jam, was designed and tested in three high schools in the Trentino Alto Adige region (Northeast of Italy). A total of, seven classes, around 150 students in the target age 14 – 16 years old, and 14 teachers were involved in the research project. This paper is presented preliminary results from data collected in 2022/2023 in three classes of the Liceo Scientifico "L. da Vinci" in Trento (Trentino Alto Adige -Sud Tirol region, Northeast of Italy).

Quali - quantitative research methodology was used favouring a holistic approach to have a more detailed and closer to the reality idea of the effects of the tested educational format. To conduct the research a set of assessment tools was developed: pre- and post-questionnaires (with open and closed-ended questions), field notes and semi-structured interviews. A metacognitive analysis was stimulated in students, using a dedicated and open-ended questionnaire to guide them in self-assessing their experience and improvement in soft and working skills, engagement and enjoyment, and disciplinary knowledge. For this paper were used student's answers to the open-ended questions referring to the metacognitive analysis at the end of the game jam experience. Qualitative data were analysed using MAXQDA-22, qualitative data analysis software, and descriptive analysis techniques. In descriptive analysis, collected data are interpreted by summarizing in view of defined categories and subcategories. A set of categories were initially defined by a deductive process and used to build up the questionnaire. Questionnaire results were processed with a qualitative content analysis

approach. After the data analysis emerged a set of specific subcategories defined in an inductive way to better illustrate the student's answers. The set categories might be changing in the future, however, table 1, are presented the categories, subcategories, and their meaning as used in the present paper to investigate and discuss the results.

Table 1: List of Categories, Subcategories, and Their Explanation, as used in Analysing Students Answers to the Metacognitive Questionnaire Adopted to Assess What Skills Were Solicitated and how Students Perceived Their Changes Before and AFTER the EcoGJ LAB

Category	Subcategory	Category description
Social skills	Group and you	Interaction sustaining engagement/attention.
		Intragroup acquaintance – openness and trust.
	Communication	Accounting for different perspectives and reaching agreement.
		Communicating ideas in positive and clear way.
		Hearing from others with a positive approach.
Working skills	Problems/solutions	Testing and finding problems in the prototype.
		Understanding the causes of the problems.
	Bridging theory and practice	Relating learning to previous experience.
		Seeing connection theory-praxis
	Timing/self-organization	Going beyond difficulties in organizing time and activities.
		Getting bogged down in minutiae.
		Increasing the attitude in meeting deadlines.
	Group working	Favouring group working as leader or supporter.
		Learning as shared experience + Resolving problems as a team.
		Overcoming conflict by management of divergencies.
Scientific/technical knowledge	Ecology contents	Understanding the meaning of ecosystem.
		Reaching precise and science-based definition of climate change.
	System thinking	Identifying ecosystem elements and inter relations.
		Understanding effects/consequence of hidden/unknow relations in ecosystems.
	Technical contents	Choosing specific mechanics to simulate/explain ecosystems.
		Choosing specific game elements to vehiculate scientific contents.
Personal skills	Participation	Investing high level of intellectual energy.
		Increasing motivation to participate actively - Time investment.
	Emotions/regulation	Enjoyment and happiness as a baseline.
		Managing positively the fatigue due to engagement/requirements.

The experimental format tested, called EcoGJ LAB – the game for ecology (EcoGJ LAB hereafter), was included in the Citizenship and Civic Education (CCE). Accordingly, with CEE discipline, the aims of the EcoGJ LAB format were to stimulate student reasoning about ecology, deepening the scientific principle of climate change causes and effects on ecosystems. The structure of the EcoGJ LAB was defined by the researchers in close collaboration with teachers to fit better the CEE needs and school time limits. Each EcoGJ LAB experimental event was organized in two parts: i) an introduction to the board games and game mechanics and ii) the proper Game jam event. The rules of the EcoGJ (based on Musil et al., 2010, Fowler et al., 2013; Fowler 2016) are illustrated in Figure 1. Each team, with no more than six students, were composed by teachers and researchers to have well-balanced groups and to facilitate the participation and inclusion of students with special needs. At the end of the event, a public presentation and the playtest of the prototype were made by each group in the presence of a panel composed of two teachers, two external students and one researcher. At the end of the game jam, the

prototypes were evaluated together with other criteria (clarity of the oral exposition, quality of the group work, accuracy of the scientific contents), and teams were awarded.

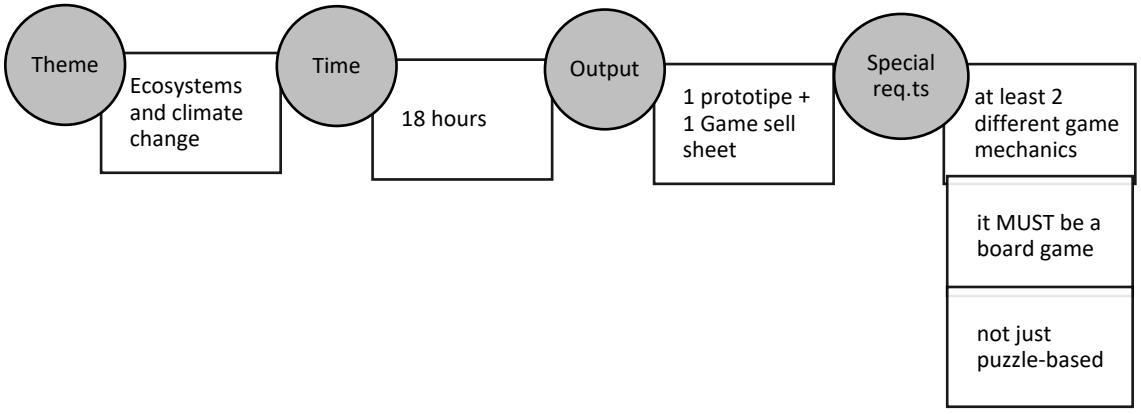

Figure 1: The Game Jam Rules and Limits for the EcoGJ LAB format as Developed and Adopted During the Testing Phase

4. Ethical Considerations

All students and their parents were informed in advance about the aim and the procedures of the study, and participation was voluntary. To protect privacy, and following data protection restrictions, data were collected in a semi anonymization way, using randomized codes, any other additional data were collected about the students except the age. Analysis of thinking-aloud protocols were performed with anonymized transcripts.

5. Results

In this preliminary investigation, data from 3 classes are reported. A total of 62 students aged 15–16 years old were involved. Incomplete questionnaires were withdrawn, and 54 questionnaires were considered valid for the analysis. The number of answers and comments in which students highlighted a change in perception of their 4 key skills level are reported in Figure 1. From a general perspective, it can be assumed that a broad range of skills was perceived as strongly applied during the game jam and increased at the end of the event. Students identified personal skills, such as the confidence in being part of the group and positive communication with others, and working skills, group working, and the ability to bring theory in praxis and problem solving especially, as the most practised and remarkably increased after the game jam event. All 54 students agreed to highlight a change in their social skills, with a slight difference in the perceived change in positive feelings as a group member (54 students) and assertive communication (44 students). It results that students are not aware of their communication skills before the game jam, but after the event, they could perceive the differences. Proper communication in their mother tongue inter pares and in technical discourses, and fluency in public speaking of the game was the most important communication skills perceived as increased after the game jam by the students.

In some cases, shy students were ready to go beyond their comfort zone, communicating and discussing in a group to share ideas and find common solutions to problems. Also, a change in working skills is reported, and specifically, 33 times mentioned as dealing with problems and finding applicable solutions was an ability highly solicited during the game jam. A total of 29 students recorded that the ability to organize the time to meet deadlines and the management of the group in working together was constantly challenged. Students recognized as group working skill was highly practised, and it was also perceived as positively increased. It emerges from the student's answers that most of them are ready to overcome personal resistance to group working if they have a common goal. They revealed that group working is most effective than working on your own, particularly in analysing problems more accurately and finding the better solution to grasp the goal. It also appears clear that the positive feeling associated with group work is the key to sustaining students' engagement in the EcoGJ. A total of 20 students also pointed out how the ability to use the theory in practical problems was a relevant skill exercised during the whole EcoGJ -LAB.

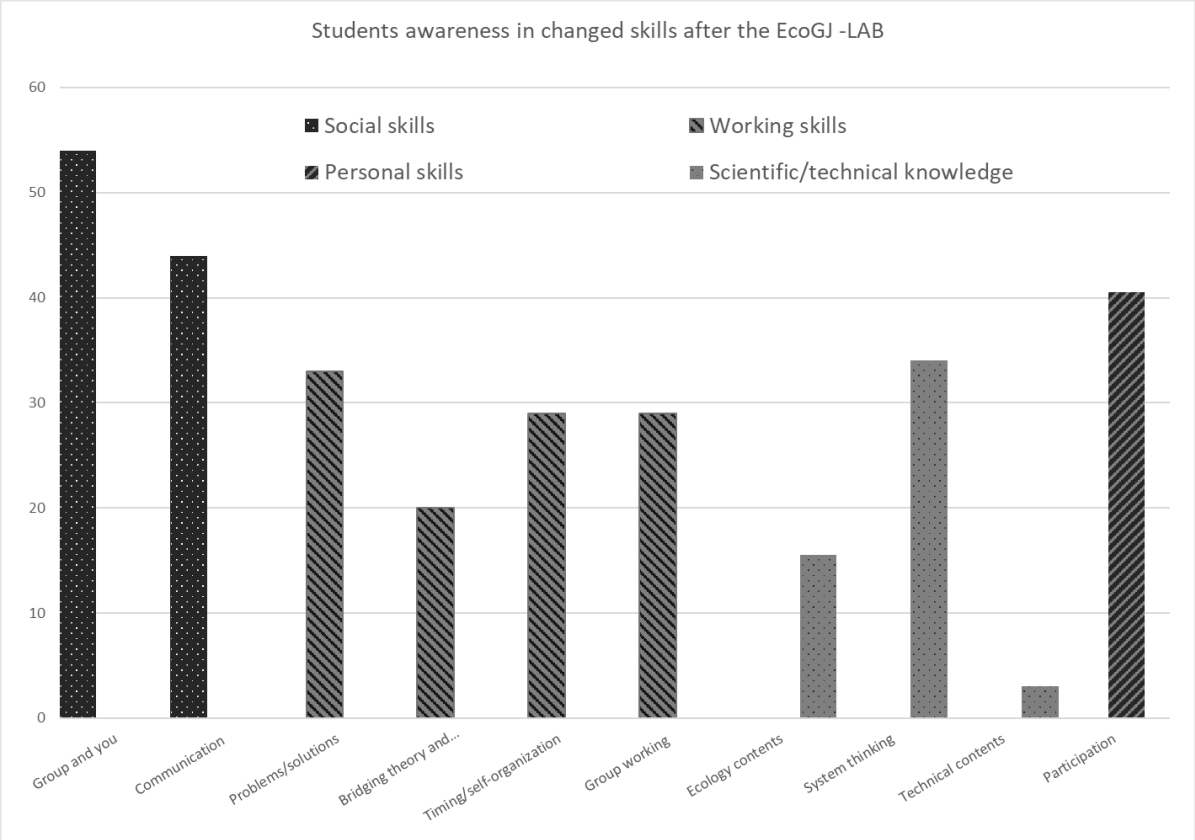

Figure 2: Graph Illustrating the Students Answers to the Metacognitive Questionnaire and the Distribution of Replies Among Skills Categories and Subcategories

Concerning the question about how the level of engagement in ecology can be influenced by a game jam event and specifically by EcoGJ LAB, an increase of interest is generally pointed out by the students. An increase in interest is demonstrated by the increase in scientific and technical knowledge mainly reached independently by students deepening ecological content to develop game prototypes. Generally, all the groups had discourses about climate change, causes and impacts on ecosystems, and possible concrete solutions to apply now in future scenario-building approaches. Fieldnotes reveal that students' in-depth research on sustainability and climate change was considerable during the event, the debate between them was heated, and in most of the prototypes, the link between ecology concepts and game mechanics was clear and explicitly declared during the presentation. Results showed that 34 students noted a change in their approach to analysing the ecological question highlighting a certain preference for adopting a more systemic approach. Moreover, 16 of them allowed that there was also an increase in their scientific knowledge in ecology but reach a certain ability in dealing with game mechanics and ecology in developing the game results hard for almost all the students. Finally, 40 students reported a very high level of engagement for all the game jam events highlighting both positive feelings increasing and negative feelings, such as fatigue and some sense of frustration, as part of the general level of engagement. Some of the students recognized that the game jam event was helpful in unlocking some hidden skills such as creativity, artistic and manual abilities and this was more relevant for fragile students who had the opportunity to be active and gain a higher level of self-esteem stimulating their interest in learning.

6. Discussion and Conclusions

This study aimed to give preliminary insights about the effect of the EcoGJ -LAB, a special game jam event developed, on students' skills and their ecology knowledge. Students displayed positive and agreeable attitudes toward the impact of the EcoGJ-LAB event on their learning and skills improvement. Concerning the first research question, these results confirm the potential of game jams in unlocking students' skills. Being game jam a co-creation event these results showed how, in an educational context, it can be effectively used to enhance students' engagement in some disciplines, to support inclusion, and to boost some key skills such as problem-solving skills, creativity, group working, critical thinking, and metacognitive processes. Especially in problem-solving skills, students reported an increase in their ability in analysing the problem in a kind of reverse engineering process and they adopted a try-and-test approach to find the best solution.

The EcoGJ LAB format appears to be effective also in stimulating students to use some key 21st-century skills like critical and system thinking. Learning in a game jam set results to be close to a building-patch work in which each student is responsible to reach, apply and exercise some skills in a personal way and by creating a concrete manufactured object as demonstrated also by other experience (Musil et al. 2010, Preston et al 2012). These findings are aligned with the literature, a great number of papers and trials confirm that game jams are effective tools for young students in unlocking their group working and communication skills such as are relevant in promoting engagement in education activities in a non-formal context (Aurava and Meriläinen, 2021, Reng et al., 2013 and Smith and Bowers, 2016)

Concerning the question about how the level of engagement in ecology can be influenced by a game jam event and specifically by EcoGJ LAB, an increase of interest is recorded by the students. Many students highlighted a growing interest in discussing ecosystem services and how they are linked to the effects of climate change. The potential of game jam in stimulating students to STEM discipline and in encouraging the in-depth discussion on climate change seems to be confirmed by the results and is aligned with the growing literature on this topic (Beça et al., 2018, Mago et al., 2019). In conclusion, EcoGJ -LAB can be considered a format belonging to the wider set of constructivist didactic activities, which can provide permanent learning, active participation, learning by doing, effective learning, fun learning, and the development of creativity. The EcoGJ LAB format is suitable, customisable especially the theme, and a potent pedagogical working method to teach STEAM and other 21st century skills. However, the nature and consequences of integrating game jams in a national formal school context require further exploration, especially about the issue of how it can be combined in formal education.

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The Dark Side of Fun: Understanding Dark Patterns and Literacy Needs in Early Childhood Mobile Gaming

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Abstract: Play has always been recognized as an essential aspect of human development, particularly during early childhood, as it contributes to learning, the formation of meanings, and experiencing the world. In today's digitalized society, early childhood education has increasingly integrated digital media into its practices, both in schools and at the family level. Mobile digital games (MDG) have received significant attention due to their impact on children's interactions, play, and learning. However, as young children engage more with MDGs, concerns about problem gaming have arisen, referring to conflicts and issues that emerge from game playing within everyday sociocultural contexts. Scholars such as Zagal et al. (2013) have identified certain game design patterns as "dark", which can be considered unethical as they manipulate players against their best interests. Given the prevalence of mobile gaming in early childhood, studying these dark patterns becomes even more crucial. This study aims to investigate the presence of dark patterns in MDG for young children (0-5 years old), through qualitative analysis. The five most popular free games for this age range on App Store (February 2023) were analysed, particularly focusing on the presence of temporal, monetary, social, and/or psychological dark patterns. The analysis uncovers the presence of temporal, monetary, and psychological dark patterns, including aesthetic manipulations, paywalls, and periodic rewards resembling gambling elements. The games also employ advertising strategies and engagement tactics that challenge young children's navigation. Parental control mechanisms offer limited safeguards, requiring continuous monitoring and parental involvement in play dynamics. The study highlights the importance of adult media and digital literacy in supporting children's online play effectively, while also emphasising the responsibility of game designers and developers to create healthier and less risky game experiences.

Keywords: Dark patterns, Game design, Mobile digital games, Digital literacy, Early childhood

1. Introduction

Play is a fundamental and essential aspect of early childhood development, with numerous studies highlighting its profound impact on children, namely until five years old. Research consistently demonstrates that play not only provides enjoyment and entertainment for young children but also serves as a crucial mechanism for learning and development across multiple domains (Waite-Jones and Rodriguez, 2022). According to Piaget's theory of cognitive development, play facilitates the construction of knowledge by allowing children to actively explore their environment, manipulate objects, and engage in imaginative and symbolic play scenarios. Through play, children develop critical cognitive skills such as problem-solving, decision-making, and abstract thinking (Piaget, 1962). Furthermore, play is closely linked to the development of social and emotional competencies. It provides opportunities for children to engage in social interactions, develop empathy, practice self-regulation, and enhance their communication, collaboration and negotiation skills. Empirical studies have consistently shown that play-based interventions in early childhood settings positively influence children's overall cognitive, social, emotional, and physical development (Blalock et al., 2019; Colliver et al., 2022; Pesce et al., 2016; Rao and Gibson, 2019).

The digitalization of contemporary society has had a profound impact on early childhood education, resulting in the integration of digital media at both school and family levels (Lindeman et al., 2021; Kumpulainen and Gillen, 2020). This also reshaped children's ways of interacting, acquiring knowledge and growing (Danby et al., 2018; Erstad et al., 2020). In this context, mobile digital games (MDGs) have emerged as a significant focus of attention, exploring their influence on children's interactions, playing, and learning (Morgade et al., 2020).

The presence of mobile technologies in children's daily lives might highlight how the blending of online and offline realms is occurring, based on how they depend on the digital environment. According to Livingstone and Pothong (2021), this premise, aligned with the integration of intelligent (AI-driven), data-centric, surveillance-oriented, and other types of 'smart' environments, by both public and private sectors, have been leading to notable advancements in persuasive design, the strategic enhancement of attention through algorithms, and the commercialization of individuals' personal information.

Despite the growing supply of media and media products - entertainment, learning or both - for children, there are few studies that focus on these subjects and reflect on younger children's interactions with digital mobile

media and how these interactions impact their literacy practices and the development of digital literacy skills (Kumpulainen et al., 2020).

1.1 The Dark Side: Design, Patterns and Digital Literacy

According to Macklin and Sharp (2016), game design is crucial in determining the mechanics, ideas, and overall gameplay experience of a game. It is through this process that the fundamental actions, themes, and interactions are established, influencing the entire play experience. Understanding and appreciating the significance of these foundational elements is key, as they directly impact children's engagement and immersion in the game. When game designers carefully craft these aspects, they create an environment that fosters meaningful play for children, enabling them to fully explore and enjoy the game.

In line with this understanding, Livingstone and Pothong's (2021) research provides a valuable perspective. Their studies with children and youth underscore the essential role of game design in bridging the gap between structured gameplay and the freedom of imaginative, child-led play – the so-called “free play”. By understanding the intricate interplay between game mechanics, concepts, and the overall gameplay experience, designers hold the power to create digital games that serve as gateways to a world of free play. Such games have the potential to stimulate children's curiosity, ignite their imagination, and empower them with a sense of agency over their play experiences.

On the other hand, the rise of unethical game design in mobile games, which focuses on maximising profits through manipulative tactics known as dark patterns (Dahlan and Susanty, 2022; Heimo et al., 2018; Zagal et al., 2013), appears to lead us towards a troubling intersection where young children and games might interact in a negative way. These unethical or manipulative design tactics raise significant ethical concerns regarding not only the user experience, but also digital literacy competencies. The use of digital technologies and media, and the growing prevalence of multimodality as Flewitt et al. (2015) and Kumpulainen et al. (2018)highlight, significantly influences children's digital literacy. Digital literacy plays a crucial role in empowering young children to navigate the digital landscape in an effective and responsible manner. These competencies are particularly relevant in today's increasingly connected world, where children are exposed to various digital platforms and technologies from an early age. Though, the rise of dark design strategies in platforms and applications aimed at these age groups poses significant challenges to their digital literacy and overall well-being - they exploit their vulnerabilities, lack of awareness, and immaturity (Tate & Warschauer, 2017).

2. The Study

In light of the previously detailed background, the objective of this study is to examine the existence of dark patterns in MDGs designed for young children aged 0-5 years old, using qualitative analysis as the research approach. In February 2023, AppStore’s five most popular free games for this age range were analysed, particularly focusing on the presence of temporal, monetary, social, and/or psychological dark patterns. The present research also seeks to prompt a critical reflection on the literacy needs of young children, their families, and educators within the context of these mobile games. By examining the presence of dark patterns in popular free games designed for children aged 0-5 years old, the study aims to shed light on potential ethical concerns related to game design.

2.1 Methods

In this study, a qualitative critical approach was employed to examine dark patterns in MDGs for young children. The analytical framework encompassed two main components: the application of an adapted approach of dark patterns heuristics and theory (Dahlan and Susanty, 2022; Zagal et al., 2013), and a formal analysis of gameplay (Lankoski and Björk, 2015).

The analysis of dark patterns involved the identification and evaluation of deceptive or manipulative design elements employed within mobile games, according to the established in Table 1. Dark patterns heuristics and theory were employed to systematically examine and interpret these design choices, considering their potential impact on players' behaviours and experiences.

Table 1: Dark patterns, subcategories and definitions. Based on Dahlan and Susanty (2022), Zagal et al. (2013), and Dark Pattern Games (https://www.darkpattern.games/)

Dark Patterns	Subcategory	Definition
Temporal: Dark patterns refer to tactics used in games to manipulate players into spending more time playing, often through deceptive or coercive means.	Playing by Appointment	Having to adhere to the game's predetermined schedule rather than being able to play on your own terms.
	Daily Rewards	Motivates players to log in daily by providing incentives, while also penalising them for failing to do so.
	Grinding	Being compelled to complete monotonous tasks in order to make progress.
	Advertisements	Compelled to view advertisements or incentivized to do so through the promise of rewards.
Monetary: Deceptive tactics that coerce or pressure players into spending money on the game.	Pay to Skip	Permitting or actively promoting players to spend money to speed up their progress in the game.
	Premium Currency	The true cost of in-game items is concealed by the exchange rate between real-world currency and virtual currency.
	Pay Wall	The game reaches a point where further progress is contingent on making a payment.
	Gambling/Loot Boxes	Using real money to participate in a game that involves an element of luck, with the possibility of receiving a prize as a reward.
Social: Manipulative techniques that leverage a player's social connections with friends and family to generate benefits for the game.	Social Pyramid Scheme	Players are incentivized to invite friends to join the game and are encouraged to continue spreading the invitation to others in their social circle.
	Social Obligation/Guilds	Due to a sense of responsibility towards one's friends, players may feel compelled to play the game even when they would prefer not to.
	Friend Spam/Impersonation	The game employs unsolicited messaging to a player's contact list or social media account.
	Fear of Missing Out (FoMO)	Players are pressured to continue playing the game by the fear of missing out on rewards or falling behind other players.
Psychological: Employ psychological manipulation techniques aimed at inducing players to	Invested/Endowed Value	Having invested significant time and money into advancing one's status in the game, it can be challenging to abandon those gains.
	Complete the Collection	The compulsion to acquire all the items, achievements, or hidden features in a game.

Dark Patterns	Subcategory	Definition
make decisions that may not be in their best interest.	Aesthetic Manipulations	The use of deceitful questions or manipulation of emotions and subconscious desires, mainly based on aesthetical game elements.
	Variable Rewards	Irregular or unexpected rewards have a greater potential to generate addiction compared to rewards provided on a predictable schedule.

The formal analysis of gameplay adopted a game-centric perspective, independent of specific player contexts. It focused on studying games as artefacts and activities, aiming to understand the game systems and how their components interact with each other. This approach blurred the distinction between games as designed systems and games as played experiences, as both aspects were considered integral to the analysis. To conduct the formal analysis of gameplay, the researchers engaged with the mobile games under investigation, actively playing and experiencing the gameplay first-hand.

The sample selection process involved conducting an examination of the top-ranking games in the App Store's children's category specifically targeting the age range of 0-5, in February 2023. The games that appeared at the highest positions in terms of popularity and downloads were identified and included in the analytical corpus. By focusing on the top-ranked games, the study aimed to analyse the games that were most widely accessible and likely to be encountered by young children and their families/educators. These games were considered influential due to their prominence in AppStore, suggesting their potential impact on children's gaming experiences and the prevalence of design elements within them.

After the selection, each game was played for at least 30 minutes using an iPhone 13.

3. Results

3.1 Sample of Games and Dark Patterns

The initial noteworthy finding within the examined sample of popular games for young children is that the majority of them, excluding Game 2, possess a distinct educational element. These games demonstrate connections with traditionally offline-based activities commonly observed within this age group, such as painting, creating object sequences, or engaging in imaginative play – the so-called “make believe”.

Another central aspect to consider is the significant inconsistency in the age ratings assigned to these games. As depicted in Table 1, all the games were classified in AppStore under the age rating "4+; Made for Ages 0 to 5". This rating is inherently paradoxical as it combines two incompatible designations—being suitable for children aged zero to four years old and also being appropriate for children older than four years old. Furthermore, certain games exacerbate this confusion by including conflicting age references in their app titles, such as Games 3 and 4, which mention suitability for children aged two and above.

Table 2: Overview of the sample of analysed games

Game No.	Title	Age Rating	In-App Purchases	Category	Developer
1	Baby colouring book for kids	4+; Made for Ages 0 to 5	Yes	Education	Bimi Boo Kids Learning Games for Toddlers FZ LLC
2	PAW Patrol Rescue World	4+; Made for Ages 0 to 5	Yes	Entertainment	Budge Studios
3	Toddler games for 2+ year old	4+; Made for Ages 0 to 5	Yes	Education	Educational Games for Kids and Toddlers. Early Learning Preschool.

Game No.	Title	Age Rating	In-App Purchases	Category	Developer
4	Kids cooking games 2+ year old	4+; Made for Ages 0 to 5	Yes	Education	Educational Games for Kids and Toddlers. Early Learning Preschool.
5	Kids Games for Drawing, Doodle	4+; Made for Ages 0 to 5	Yes	Education	Bini Bambini Academy

Note: the table above was developed according to the information available on AppStore.

The analysis of the dark patterns present in each of the five games included in the sample (Table 2), through the implementation of the taxonomy presented in Table 1, and based on Dahlan & Susanty (2022), Zagal et al. (2013), and Dark Pattern Games (https://www.darkpattern.games/) is presented in Table 3. The presence of each dark pattern was categorised with a number from zero (when a dark pattern is not identified in the game) to four (when a dark pattern was identified in the game and it detrimentally affects both the gameplay experience and the player's mindset), according to the heuristic evaluation proposal developed by Dahlan & Susanty (2022).

Table 3: Dark patterns in the sample of games according to the taxonomy presented in Table 1

Dark Patterns	Subcategory	Games				
		1	**2**	**3**	**4**	**5**
Temporal	Playing by Appointment	0	0	0	0	0
	Daily Rewards	0	0	0	0	0
	Grinding	0	0	0	0	0
	Advertisements	3	4	2	2	2
Monetary	Pay to Skip	0	1	0	0	0
	Premium Currency	0	0	0	0	0
	Pay Wall	4	0	4	4	4
	Gambling/Loot Boxes	0	0	0	0	0
Social	Social Pyramid Scheme	0	0	0	0	0
	Social Obligation/Guilds	0	0	0	0	0
	Friend Spam/Impersonation	0	0	0	0	0
	Fear of Missing Out (FoMO)	0	0	0	0	0
Psychological	Invested/Endowed Value	0	0	0	0	0
	Complete the Collection	4	3	4	4	4

Dark Patterns	Subcategory	Games				
		1	2	3	4	5
	Aesthetic Manipulations	4	3	4	4	4
	Variable Rewards	0	1	0	0	0

From the four categories of dark patterns, only social dark patterns were considered absent from these games. All the remaining categories – temporal, monetary, and psychological – were to some extent present in the games. All games presented both aesthetic manipulations and strategies to coerce players into completing the collection, with these subcategories of patterns heavily affecting their play experience – 19 out of 20 possible points for each subcategory. Similarly, paywalls were also found as a very characteristic dark pattern in these popular MDGs aimed at children, being present in four of the five analysed games, always to the highest possible degree. Examples of this are presented in Figures 1 and 2, representing an intricate of monetary and psychological dark patterns, including paywalls and the inherent aesthetical call to complete a collection.

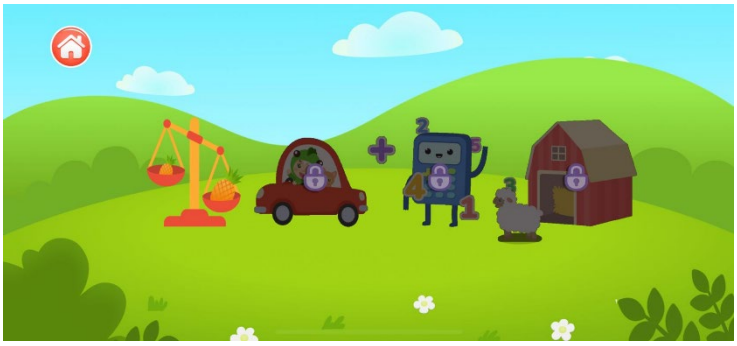

Figure 1: Screenshot from Game 3 menu (Source: Toddler games for 2+ year old | Educational Games for Kids and Toddlers. Early Learning Preschool)

Figure 2: Screenshot from Game 5 menu (Source: Kids Games for Drawing, Doodle | Bini Bambini Academy)

Advertisements were present in all games, although expressed differently in the sample – whether in terms of type or frequency. Game 1 and Game 2 was seen as having a significant impact on players' experiences and mentality, as represented in Figure 3. On the other hand, Games 3, 4, and 5 were seen as being minorly affected by the presence of advertisements. Pay to skip was present only in Game 2 but, even there, is analysed as posing little to no harm to the playing experience.

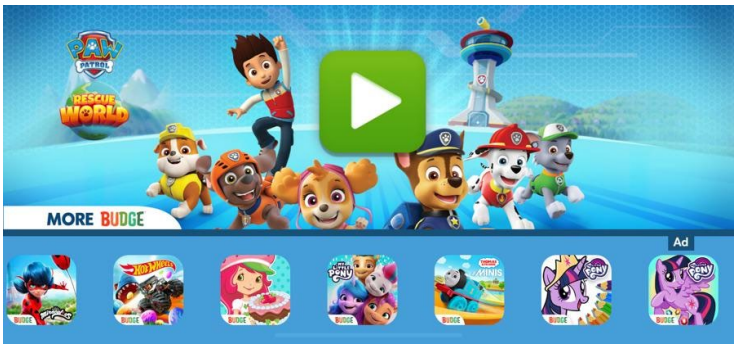

Figure 3: Screenshot from Game 2 menu (Source: PAW Patrol Rescue World | Budge Studios)

Social dark patterns, which leverage social networks to encourage game sharing among players through mechanisms like social obligation, were not observed in the analysed games, given their target age demographic.

3.2 Aesthetic Manipulation and Paywalls

The analysis of the games uncovers various noteworthy findings regarding the graphical representation of locked content, deceptive paywall mechanisms, periodic rewards, personalised plans, and the pervasive nature of in-app purchases. These findings shed light on the intricate design elements and monetization strategies employed within these MDGs for young children.

The aesthetically pleasing graphical representation of locked playable content – exemplified in Figures 1 and 2 – possesses the potential to evoke a stronger inclination towards purchasing or desiring ownership of said features. A feeling of dissatisfaction stemming from the absence of these features is present along with this effect. Consequently, the visually enticing paywalls, strategically implemented early in the game with minimal free-to-play content, appear to constitute a complex dark pattern. In essence, this design comprises a sophisticated approach that combines financial coercion (the paywalls, according to Table 1's model) with psychological coercion (the urge to complete collections and aesthetic manipulation, also according to Table 1's model).

Furthermore, within this domain, both Game 3 and Game 4 employ an initial, albeit deceptive, "paywall" mechanism. This design creates a false impression that payment is necessary for progression, even though it is not. This deceptive practice is accomplished by manipulating the size and placement of the close option within the paywall, intentionally making it less noticeable compared to the more prominent "continue" option, as depicted in Figure 4.

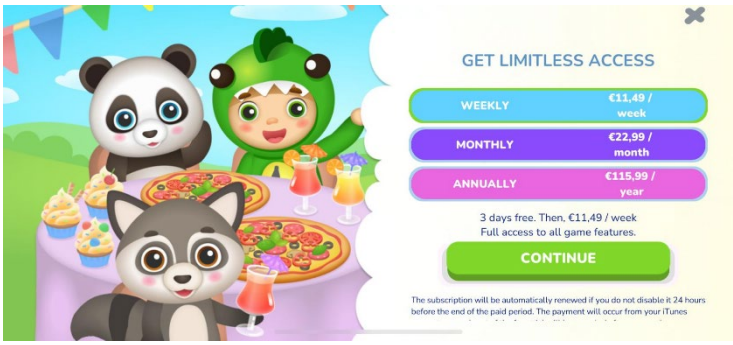

Figure 4: Screenshot from Game 4 initial paywall (Source: Kids cooking games 2+ year old | Educational Games for Kids and Toddlers. Early Learning Preschool)

Within a spectrum that is potentially more closely linked to gambling, it is noteworthy that Game 2 also offers periodic rewards. However, it is important to note that these rewards, although unpredictable, should not be classified as loot boxes.

In a rather distinctive way, Game 5 initially appears to target adult users by offering the option to create personalised plans for each child based on their individual interests. However, when outlining such a plan, users are redirected to a purchase screen where the most expensive option is consistently labelled as the "best value," and emphasis is placed on the "free trial" option. Conversely, the option to continue without subscribing is presented in a less prominent manner, located in the upper left corner.

This critical analysis serves as an overarching examination of the games, highlighting a significant aspect: despite presenting themselves as free, they function as a framework for facilitating – and persuading – in-app purchases. Therefore, the portion of gameplay that is effectively free to play is deliberately very limited. This trend is consistent across all games, but it becomes especially prominent in Games 3 and 4, which, being from the same company, share very similar monetization strategies.

3.3 Advertisement and Parental Control

The analysis of the games reveals noteworthy findings regarding their advertising strategies, engagement tactics, cross-marketing approaches, and consideration of parental control mechanisms.

In the context of game 2, the advertisements manifested as pop-ups that were both repetitive and visually similar to the gameplay, creating an illusion of seamless continuation. As a result, the act of clicking on these advertisements becomes nearly unavoidable, particularly when considering the limited literacy and cognitive abilities of young children. Still concerning Game 2, it appears to implement an engagement strategy that resides at the intersection of aesthetic and advertising considerations. This strategy leverages the recognizable imagery and narrative associated with a well-known franchise among the target age group, Paw Patrol, in order to attract prospective players. Additionally, as depicted in Figure 3, other games promoted within the same context seem to employ a comparable approach with other franchises – Miraculous: Tales of Ladybug & Cat Noir; Hot Wheels; Strawberry Shortcake; My Little Pony; and Thomas & Friends.

Despite not relying on popular franchises, Games 3 and 4 employ advertising strategies to engage in cross-marketing various games and applications from the same company. Additional advertising strategies can be observed in Game 5, notably through the presence of in-game visual references throughout the gameplay experience. Moreover, the inclusion of labels such as "try for free" further exemplifies the use of advertising techniques within the game (bottom left corner in Figure 2).

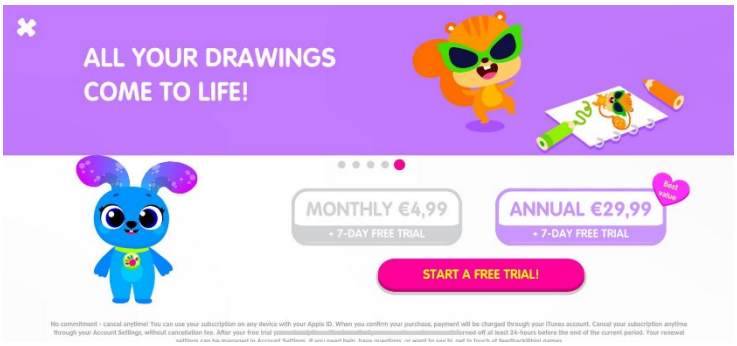

Figure 5: Screenshot from Game 5 subscription options (Source: Kids Games for Drawing, Doodle | Bini Bambini Academy)

Despite incorporating dark patterns within their game design, the examined games also appear to consider certain parental control mechanisms, particularly those associated with in-app purchases. This aspect is evident across all games, and is exemplified in Figures 6. Even though they are very simple, they can be considered relatively effective for young children – e.g. indicating the year of birth or doing a basic mathematical operation.

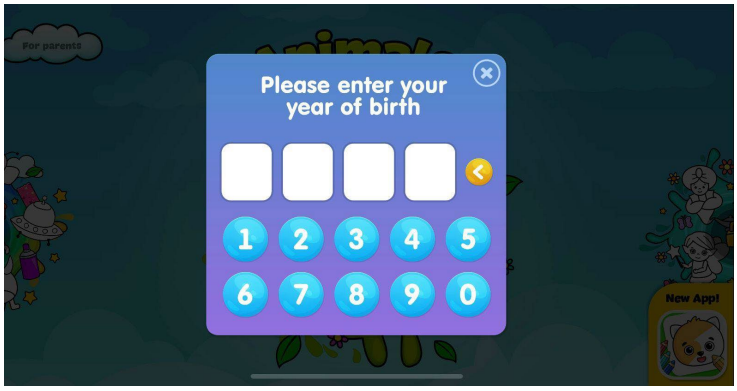

Figure 6: Game 1's in-app purchase parental control system (Game source: Baby colouring book for kids | Bimi Boo Kids Learning Games for Toddlers FZ LLC)

3.4 Early Childhood Mobile Gaming and Literacy Needs

The study's results highlight a significant finding: the primary literacy needs in children's engagement with mobile games rest with the adults who facilitate or supervise their interactions. This emphasises the importance of promoting adults' game and digital literacy to support children effectively. Additionally, the study raises questions about managing associated risks while fostering critical and empowering approaches and learning, particularly when considering dark patterns within the context of childhood.

Based on the age range and the games examined, a significant finding emphasises that the primary literacy needs lie with the adults who facilitate or supervise children's engagement with mobile games. This is evident, for example, when considering ambiguous age ratings, as it highlights the responsibility of adults in making decisions. It ultimately depends on their assessment of whether a game is suitable for the child's developmental stage, level of maturity, and need for stimulation.

Therefore, besides digital literacy in general, the obtained results emphasise the need to promote adults' game literacy. By embracing game literacy, parents can facilitate learning, critical thinking, and a richer gaming experience for their children. In this sense, we can adopt Zagalo's (2010) concept of creative game literacy, which contends that game literacy should concentrate on both understanding games (decoding) and designing games, highlighting the wide range of skills that families and educators need to develop.

According to Herdzina and Lauricella (2020), the support required for the development of children's media literacy is categorised based on age groups, which do not align with the age range defined by the AppStore (see Table 1). Within this framework, specific attention is given to children aged zero to two years, who face challenges (or vulnerabilities) in critically analysing media due to their specific and age-related developmental characteristics. Consequently, adult support during this stage should focus on engaging with the media together and, in the context of this study, engaging in co-play. Similarly, for children aged three to four years, there is notable cognitive development, although difficulties persist in distinguishing between fantasy and understanding abstract concepts. Therefore, when children of this age engage with mobile games, adults accompanying them are encouraged to gradually introduce elements of critical analysis and foster their agency in their own play and media consumption in general.

Moreover, the results sustain a need to re-contextualize dark patterns and associated literacy practices within the context of childhood, particularly early childhood. Prominent researchers have been placing dark patterns literacy within media education through an agency-driven perspective, which acknowledges that "some players deliberately find pleasure in engaging in processes designed to make them spend time and money, although they recognize them as such" (Dupont and Malliet, 2021, p. 18). The developmental characteristics and lack of maturity of certain age groups, such as the one discussed here, lead us to rethink this conceptual stance. While we may want to promote a critical and empowering approach, how can we do so while managing the associated risks?

4. Discussion

In this study, we aimed to examine the presence of dark patterns in MDGs designed for young children aged 0-5 years old. The findings revealed a combination of positive and concerning aspects within the analysed games, highlighting two complementary points: (a) the need for adult media and digital literacy and responsible management of children's engagement with these games; and (b) the need to foster ethical game design patterns within the industry, mainly focusing on the specific characteristics of this age range.

Most of the examined games demonstrated educational elements that aligned with offline activities commonly observed in young children, such as painting and imaginative play. This shows how diffuse the distinction between online and offline environments is and how they mutually influence the play environments in which young children engage. However, significant inconsistencies were observed in the age ratings assigned to them, which might lead to confusion for families and educators – which games are and are not appropriate according to the child's developmental stage? This discrepancy calls for clearer and more accurate age ratings, so that adults can make informed decisions about the suitability of games for their children.

The analysis of dark patterns in the games uncovered the presence of temporal, monetary, and psychological dark patterns to varying extents. Aesthetic manipulations and paywalls were identified as prominent, impacting the gameplay experience and potentially influencing purchasing behaviour. Although social dark patterns were absent, other categories were prevalent, indicating the need for careful consideration of the design elements in these games. Moreover, aesthetic manipulation was identified as a particularly complex dark pattern in the

sample – visually enticing locked content, and deceptive paywall mechanisms. It creates a sense of desire and dissatisfaction, coercing players into making purchases or completing collections. Periodic rewards, although not classified as loot boxes, exhibited similarities to gambling elements. Additionally, personalised plans with pricing manipulation were employed to encourage subscriptions. These strategies mainly targeted adult users.

Advertising strategies and engagement tactics were observed in the games, with pop-up advertisements and cross-marketing approaches being employed. These strategies aimed to increase engagement and attract players, but they also posed challenges for young children' to navigate the game without clicking on them. Parental control mechanisms related to in-app purchases were present, offering a small number of safeguards. Despite this, the results of the analysis conducted point to the pressing need for continuous monitoring and parental involvement - without this support, children may engage in negative play experiences that do not address their learning, stimulation and entertainment necessities. Hence, it is still not clear how these patterns can promote an adverse gaming experience, triggering feelings of frustration, incapacity, and other aggressive behaviours (Kahila et al., 2022).

Overall, the study emphasises that the primary literacy needs in children's engagement with mobile games lie with the adults who facilitate or supervise their interactions. Along with media and digital literacy, adult game literacy is essential for supporting children's online play effectively. Therefore, promoting adults' game literacy can enhance children's learning, critical thinking, and gaming experience. The concept of "creative game literacy" (Zagalo, 2010), which encompasses understanding and designing games, might provide a framework for developing the necessary skills among parents and educators, in various educational contexts.

The other crucial factor of this discussion is how the issues of addiction and other problems commonly associated with gaming can be attributed not only to the child, their family, or supervisory factors but also to the game design itself. In other words, the obtained results highlight how the responsibility for creating a healthier and less risky relationship between children and games lies not solely with the child's literacy, adult game literacy or families/educators' decision-making, but also with the game designers and developers. Moreover, it is important to rethink these practices in light of existing business and monetization models, making families and educators aware of the implicit costs and impacts of free games such as the ones analysed.

Furthermore, the study raises important questions about managing associated risks while fostering critical and empowering approaches, particularly when considering dark patterns within the context of early childhood. Re-contextualizing dark patterns and associated literacy practices within the developmental characteristics and maturity levels of young children seems crucial. Balancing the promotion of critical thinking and agency with the responsible management of risks requires further exploration and consideration, in order to enrich the literature, and to identify and disseminate good practices that can be replicated, both in the context of video game producers, but also in the context of adults with educational responsibilities..

4.1 Limitations and Future Directions

Despite the valuable insights provided by this research regarding the presence of dark patterns in mobile games for young children, there are several limitations that need to be considered. Firstly, the study's sample size was limited, focusing on a small selection of popular MDGs for young children. While efforts were made to choose representative games, the findings may not be generalizable to the entire population of games targeting this age group. Future studies could expand the sample size, include a wider range of games and consider other providers to obtain a more comprehensive understanding of the prevalence and impact of educational elements and dark patterns.

Secondly, the categorization and assessment of dark patterns involved a degree of subjectivity, despite adopting a standardised evaluation framework. Different researchers may interpret and assign scores to dark patterns differently, potentially leading to variations in the analysis. To enhance the reliability and validity of dark pattern assessments, future research could involve multiple evaluators and employ inter-rater reliability measures. Comparing children's and adult's gameplay experiences could also provide rich insights to critically analyse the perceptions and impacts of dark patterns.

Another limitation is the inconsistency in age ratings and app store classifications. The analysis revealed that the assigned age ratings were paradoxical and often conflicting, making it challenging for educators and families to determine the suitability of games for their children. However, the study did not investigate the actual impact of these inconsistencies on children's gameplay experiences or parental decision-making. Further research could explore how misleading age ratings and classifications affect children's engagement and parents' choices regarding game selection.

Having this in mind, conducting longitudinal studies that value children's voices, would provide valuable insights into the long-term effects of mobile games on young children's development. By tracking children's gameplay experiences, their behaviours, learning and competencies over an extended period, researchers can better understand the impact of both educational elements and dark patterns on their cognitive, social, and emotional outcomes.

By shining a light on these dark patterns, this research study aims to contribute to a broader discussion on responsible and ethical game design practices. It encourages researchers, developers, families, and educators to reflect on the impact of these design strategies on children's well-being, literacy development, and overall digital experiences. Ultimately, the goal is to promote the creation of more inclusive, engaging, and ethically designed digital experiences for young children.

Future studies should also aim to delve into the intricacies of game monetization strategies in a more detailed manner. One particular area of interest could be the comparison between free and paid games and their respective target audiences. This research could become particularly relevant with the recent expansion of game platform subscription services to mobile devices, for example, with Apple Arcade.

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Barriers and Hindrances to the Effective use of Games in Education: Systematic Literature Review and Intervention Strategies

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Abstract: Games play a central role in human culture, as well as in interaction, interpersonal relationships, and overall development. Based on these premises, game-based learning (GBL) has been increasingly studied as a form of pedagogical innovation in formal and non-formal education. However, the implementation of these types of interventions in real educational settings has faced several barriers and constraints that reduce their possible impact. In this context, the present study aims to fulfil two aims: (a) mapping the main obstacles experienced in the implementation of GBL approaches in educational contexts; and (b) proposing an intervention diagram that matches each type of barrier with potential strategies to address it. Towards these aims, a Systematic Literature Review (SLR) was conducted, following the PRISMA methodology and guidelines. This included screening and eligibility processes based on inclusion criteria, which were defined considering the research's aims. Non-peer-reviewed research and studies aimed at other pedagogical approaches, such as gamification, were excluded to obtain a final sample of 11 studies and 1952 individuals, with an average of 195.20 participants per study (*SD* = 266.14). Through the analysis of the studies, a model of four types of barriers emerged: (1) attitudinal and behavioural barriers; (2) school policy barriers; (3) technological and material barriers; and (4) game literacy barriers. Through the critical evaluation of the barriers emerging from the analyzed empirical studies, we propose some potential methodological strategies that might support practitioners in overcoming them. This includes: (a) the implementation of a co-creation and participatory-driven methodology; (b) the appropriate selection of analogue, digital, or hybrid games; (c) the inclusion of the different educational stakeholders in the process; and (d) the promotion of GBL training within the projects.

Keywords: Game-Based Learning, Education, Games, Barriers, Systematic Literature Review

1. Introduction

Games have been a part of human culture for millennia, serving various purposes from entertainment to socialization and skill development. In the past decades, advances in digital technology have facilitated the emergence of game-based learning (GBL) as a form of pedagogical innovation in formal and non-formal education. One of the main advantages of GBL is its ability to engage students, which can help them stay motivated and focused on learning (Hartt et al., 2020). Additionally, it encourages active learning and can be personalized to fit the needs of individual students (Orji et al., 2017). Games also provide immediate feedback, which can help students learn more quickly and understand their mistakes (Plass et al., 2015). Collaboration is another benefit of GBL, as it promotes social skills and teamwork (Chen and Law, 2016). Studying GBL must, therefore, represent "the integrated viewpoints of cognitive, motivational, affective, and sociocultural perspectives", including both game design and game research as complementary aspects of the learning process (Plass et al., 2015, p. 278).

Despite the potential of GBL, the implementation of these types of interventions in real educational settings has faced multiple barriers and constraints that reduce their possible impact. Barriers related to the cost of equipment (Moizer, et al., 2009), the inequities in access to technology (Hsu, et al., 2011), entertainment risks to education activity (Rowan, 2016; Baalsrud et al., 2013), the available time required to implement games in one day lesson (Justice and Ritzhaupt, 2015; Baek, 2008), teachers gender and their motivation and abilities to deal with technology (Hamlen, 2010; Justice and Ritzhaupt, 2015), lack of game customizations (Embi, 2008; Javora et al., 2021), difficulties to get game analytics and to analyze the student progress (Hauge et al., 2014), educators and parents worried about using games in education (Barko and Sadler, 2013; Koh et al., 2011), are a portion of the constraints caused by the adoption of games in education. To maximize the potential of GBL, it is crucial to identify and address these barriers and develop effective intervention strategies. To propose these strategies, we conducted a Systematic Literature Review (SLR), following the PRISMA methodology and guidelines (Page et al., 2021).

2. Method

2.1 Eligibility Criteria

The main research aim was used to establish the eligibility criteria. To be included, studies had to approach GBL interventions, with a specific focus on the obstacles experienced in its implementation in educational contexts. Empirical peer-reviewed research within this scope was included in the sample. Conversely, studies that were excluded included book reviews, systematic reviews, and theoretical articles in any form. Additionally, studies that focused on Gamification instead of GBL were excluded.

2.2 Information Sources and Search Strategy

The electronic search was carried out across various databases, namely All Collections in Web of Science, EBSCO, ERIC, IEEE Xplore, Elsevier, and Springer, through the subsequent survey of the equations:

- "game-based learning" AND barriers;
- "game-based learning" AND challenges;
- "game-based learning" AND obstacles;
- games AND education AND barriers;
- games AND education AND challenges.

The definitive search for retrieving all relevant results from the databases was performed on November 14, 2022.

2.3 Selection Process

After the search results were imported, Endnote X9 was employed to automatically remove duplicate entries. The results were subsequently exported to an Excel sheet, where they were screened in two phases. The first phase involved reviewing the titles and abstracts of the studies and assigning labels of 'included' or 'excluded' following the pre-defined inclusion and exclusion criteria. The second phase entailed a thorough full-text screening of the studies deemed eligible during phase one. This process resulted in a final sample of 11 studies and is systematized in Figure 1.

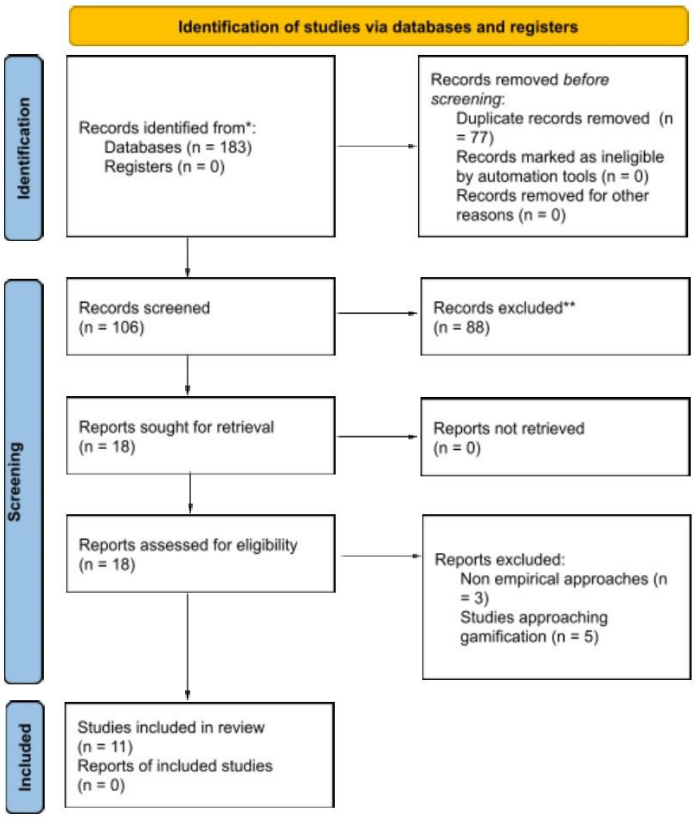

Figure 1: Flow diagram showing the process of the identification studies to include in the review

2.4 Data Extraction and Analysis

For purposes of analyzing the selected articles, the sample was subjected to coding to identify the most frequent barriers and hindrances to the effective use of games in education. Afterwards, a more qualitative lens was used to explore each barrier and its contextual factors, according to the authors. Critical reflection and triangulation with the existing conceptual models allowed the development of a proposal for an intervention diagram. Statistical analysis techniques (descriptive statistics) were also employed to analyze sample characterization data.

3. Overview of the Results

The obtained studies (*N* = 11) resulted in an aggregate sample of 1952 individuals, with an average of 195.20 participants per study (*SD* = 266.14). It is important to note that five articles had teachers as participants (45.45%), two had education students/pre-service teachers (18.18%), one had students as participants (9.09%), while another one adopted a multistakeholder approach (9.09%), to include the views of parents, youth, and teachers. The study conducted by Marklund and Taylor (2016) only mentioned the inclusion of 17 classrooms in the study without mentioning the number of individuals included. The sample description is schematized in Table 1.

Table 1: Characteristics of the studies' participants (*N* = 11)

Article	Sample
(Alqurashi and Alqurashi, 2017)	930 teachers
(Arnab et al., 2016)	122 students
(Chen et al., 2020)	231 teachers
(Hu and Sperling, 2022)	130 pre-service teachers
(Jääskä and Aaltonen, 2022)	22 teachers
(Kaimara et al. 2021)	170 pre-service teachers
(Khodabandeh, 2022)	75 students
(Manesis, 2020)	148 teachers
(Marklund and Taylor, 2016)	17 classrooms (participants not specified)
(Martins and Oliveira, 2019)	18 teachers
(Sousa et al., 2017)	106 teachers, parents, and youth

4. Barriers to the Effective use of Games in Education

Through the analysis of these articles, it is possible to highlight and discuss the most common barriers to the implementation of game-based interventions in educational settings, as follows.

4.1 Attitudinal and Behavioral Barriers

Although most data seems to reinforce that the school community recognizes the potential of using and creating games for learning purposes, namely considering their role in communication, transferable knowledge, problem-solving skills, and self-expression (Sousa et al., 2017), different attitudinal and behavioural barriers become apparent in the analyzed sample. These barriers can be grouped into different categories and subcategories, as represented in Figure 2.

Figure 2: Attitudinal barriers to GBL interventions, according to the sample

The micro-level of attitudinal barriers can be understood by how the beliefs or behaviours of different individual stakeholders can work as drivers or hindrances in the implementation of GBL interventions. According to Martins and Oliveira (2019), teachers and educators tend to rate their technological knowledge as low, which extends to their lack of experience in incorporating games into their teaching practice. Although this can be better explained by the game literacy dimension that we will later approach, it can also be examined as an attitudinal issue, since it stems from a structural disbelief in one's ability to support their pupils to thrive in innovative pedagogical approaches.

Regarding students, analysis of the sample showed some unexpected results regarding their negative attitudes towards GBL. When implementing GBL interventions, depending on learners' profiles, they may prefer more conventional teaching methods, including lectures, written assignments, and exams, that allow them to play a more passive role in the learning process (Jääskä and Aaltonen, 2022). This aspect was also found in data from Sousa et al. (2017), which showed that students have much more positive attitudes toward the recreational role of games than towards their pedagogical role.

We advance potential reasons for a possible disconnect between some learners and the GBL approaches. One potential reason is student frustration with cases of lack of clear instructions in GBL which are often related to the issue of instructors' low game literacy, which will be addressed below. This can also be motivated by an apparent disconnect between an educational game and the educational objectives that were initially proposed to the student. For this aspect, the promotion of reflection in debriefing processes becomes an important protective factor against loss of interest as well as a promoter of meaningful learning (Jääskä and Aaltonen, 2022; Marklund and Taylor, 2016).

Transversal to the three groups of individuals – educators, families, and students – is the attribution of a negative connotation to games as solely and exclusively a form of entertainment. That is to say, there is a noticeable cleavage between the idea of "serious games" – perceived as having relevance and pedagogical value – and commercial games – perceived as a mere "waste of time" (Sousa et al., 2017). It should be noted that considering the current state of the art, this can be seen as a fallacy, since research by now has been documenting the learning potential of both digital and analogue games, from learning about probabilities with Settlers of Catan (Austin and Molitoris-Miller, 2015) to high-level decision making in Counter-Strike: Global Offensive (Kiourti, 2022).

Regarding the macro-level of attitudinal barriers from both school and policy-makers' perspectives, it is important to note the existence of negative attitudes related to GBL that negatively impact its potential implementation (Kaimara et al., 2021). On a societal level, one of the most salient attitudinal barriers is the so-called "digital natives" narrative. There is a prevalent notion, especially associated with pre-service or younger teachers, that they are completely familiar with how to implement innovation-driven pedagogical strategies – including GBL – due to the context in which they have grown up. This discourse can be understood as a barrier in that it promotes preconceived notions about individuals' backgrounds, socioeconomic contexts, technological access, and literacy, which runs against the inclusive potential of games (Hu and Sperling, 2022; Marklund and Taylor, 2016). Although this macro-level of attitudinal barriers includes policy-makers' attitudes as explored by Kaimara et al. (2021), the impact of their effective measures in the daily educational context is framed in another set of barriers that will be now explored.

4.2 School Policy Barriers

While research can reinforce the pedagogical benefits of game-based approaches, they often come up against institutional issues faced by schools and higher education institutions. These issues can even extend to non-formal education contexts. The analyzed sample of articles highlights issues related to limited instructional time available to educators for including innovative pedagogical practices in their work. This is exacerbated by difficulties in aligning games with learning goals as stated by a national curriculum (Alqurashi and Alqurashi, 2017; Hu and Sperling, 2022; Marklund and Taylor, 2016). The lack of policies and frameworks for supporting this task makes it more challenging to ensure the desires of all stakeholders – students, teachers, schools, and education ministry – are met (Kaimara et al., 2021).

4.3 Technological and Material Barriers

Access is a necessary precursor to participation in media, as well as participation in democratic civic structures (Carpentier, 2011). From the standpoint of this premise, the thematic analysis of our sample showed a set of technological and material barriers that impact GBL interventions in the educational context, including funding constraints.

For technological barriers, several studies in the sample emphasized the negative impact of infrastructure issues in GBL interventions, such as inadequate internet network service, outdated computers, or a lack of technical staff and software (Alqurashi and Alqurashi, 2017; Jääskä and Aaltonen, 2022; Kaimara et al., 2021; Manesis, 2020; Marklund and Taylor, 2016). This combined with the literacy phenomenon and the inability of teachers to solve technical issues that may emerge during interventions contribute to a sense of frustration and negative game experiences both for teachers and students (Jääskä and Aaltonen, 2022).

Material barriers are associated with the lack of games *per se*, or the lack of funding to acquire them. Lack of games – more specifically educational games in schools – is a salient aspect of this study, as well as their high cost (Alqurashi and Alqurashi, 2017; Jääskä and Aaltonen, 2022; Manesis, 2020). Besides games, a more general issue of lack of funding for educational activities is also noted as a fundamental hurdle to the implementation of GBL in these contexts (Kaimara et al., 2021).

As stated above, there are effective technological barriers, but there are also skill gaps and low awareness of one's skills (Martins and Oliveira, 2019). This brings us to the issue of game literacy.

4.4 Game Literacy Barriers

Chen et al. (2020) explored how the lack of teachers' game literacy impacted GBL interventions, through a framework that distinguishes multiple literacy dimensions. These included:

- the literacy of instructional design of GBL, or how teachers were able to correlate game design and learning outcomes, before adopting such strategies in their classrooms;
- the literacy of evaluation of GBL, which could also be seen as an attitudinal dimension, comprising teachers' beliefs regarding the adoption of games, and how these impact students' motivation and cognitive gains;
- the literacy of organization and management of GBL, which comprises the required skills to manage technological and material barriers;
- basic games literacy, associated with games selection and the overall notion of the concepts, considering how this is associated with their ability to engage students in the learning process;
- and high-level game literacy, which represents systems-based game thinking.

Teachers' lack of game literacy is also highlighted by Hu and Sperling (2022), emphasizing how they tend to perceive games as supplementary activities and not as pedagogical tools in themselves. This might be associated with other recorded barriers, like the need for better awareness of the relationship between game mechanics and learning (Jääskä and Aaltonen, 2022) or the difficulties in spotting students' issues with the game interface (Marklund and Taylor, 2016). Overall, it seems relevant to acknowledge how game literacy is not only important for monitoring gaming sessions but also for the success of all the contextualizing activities surrounding them, most specifically critical reflections and debriefings (Marklund and Taylor, 2016).

Game literacy needs to arise from training programs that prepare educators to fully support their pupils in the context of game-based interventions. Analysis shows how current teacher-preparation programs lack exposure to game-based instruction (Hu and Sperling, 2022), aligned with an overall lack of Information and Communications Technology (ICT) training that neglects the role of playfulness in education (Kaimara et al.,

2021). This issue needs to be addressed since providing educators with knowledge about the pedagogical value of games is considered central to their democratization in education. Martins and Oliveira (2019) propose making training more accessible and appealing and even integrated with pre-service teacher education.

5. Potential Strategies for Dealing With the Identified Barriers

We propose some potential methodological strategies that might support practitioners in overcoming the identified barriers, as suggested by our critical analysis identifying these barriers. The strategies comprise: (a) the implementation of a co-creation and participatory-driven methodology; (b) the critical option for using analogue, digital, or hybrid games; (c) the inclusion of different educational stakeholders in the process; and (d) the promotion of GBL training within projects.

5.1 Co-Creation

Co-creation is an ontological position that arises from the constructivist scientific paradigm, adopting a relativist position and believing that reality is a construction of the human mind. For the specific issues of GBL and gaming in general, the constructivist paradigm is relevant since it focuses on how participants construct meanings from their reality, emphasizing the variety and multiplicity of interpretations (Guba and Lincoln, 1994).

More concretely, co-creation in this context means that the voice of the player is also included in the creative processes. Namely, the audience moves from a more passive role to a more active role in defining the game itself (Kafai, 2006; Rüller et al., 2022). In the context of learning, it is related to person-centred learning or personalized learning environments (Zhang et al., 2020).

Co-creation implies a certain willingness to engage with participants and incorporate their ideas into a project through different participatory approaches, for instance, design thinking (Ind and Coates, 2013). Creativity and co-creativity developed through play-inspired design thinking have the potential to sustain students' practices and mindset long term, which will impact their engagement with the community (Arnab et al., 2019).

5.2 Analogue Games VS Digital Games

In the early days of the academic discussion on GBL, James Paul Gee (2005, p. 34) supported the conceptual definition of this field by establishing the principles of learning promoted through "good games". For the Gee, a "good" game needed intrinsically operationalize the latest scientific principles of skill acquisition in cognitive science in its gameplay which included: identity; interaction; production; risk-taking; customization; agency; well-ordered problems; challenge and consolidation; "just-in-time" and "on-demand" situated meanings; pleasantly frustrating; system thinking; explore, think laterally, rethink goals; cross-functional teams; and performance before competence (Gee, 2005).

Although the principles described above have been thought of in a primarily digital context, they can be extended to board games. The learning potential of this type of game is nowadays well-founded in literature, with an emphasis on the role of play in human development (Gobet et a., 2004), and how these artefacts represent each society's culture (Booth, 2021).

While research has empirically supported the learning potential of digital games, namely at the motivational, engagement, and confidence levels (Abdul Jabbar and Felicia, 2015), more recent approaches have emphasized specific advantageous aspects of analogue games for both educators and students. These include skills such as collaboration, communication, creativity, problem-solving, and decision-making. Analogue games are very much characterized by their flexibility, and how they can be easily adapted to the requirements of any specific classroom or group of players (Maratou et al., in press).

The choice between digital, analogue, or hybrid games can prove crucial for the sustainability of an intervention given the issues with technological barriers, or other micro-level or school policy barriers to GBL adoption. None of these options is intrinsically more viable or more pedagogical than another. Their contextual feasibility depends on a detailed assessment of the target audience, available funding, existing technology, the literacy of trainers and trainees, and possible accessibility needs, among other aspects.

5.3 Multistakeholder Approach

The concept of stakeholder is used broadly to define all those who affect or are affected by the achievement of an organization's purpose (Freeman, 2010), often characterizing a systemic focus on the relationships between them. The label "multistakeholder approach" intends to emphasize interventions where different voices are heard and included in the process of educational change through play, regardless of their inherent power

relations. This horizontality means that the perspective of a teacher or a pedagogical director cannot be higher-valued than that of a student.

The methodological proposal in this paper aims to address school policy barriers, based on the notion that including different voices in educational decision-making enhances satisfaction, trust, and a sense of belonging, for educators (Rosales, 2019), families (Gülcan and Duran, 2018), and students (Mitra, 2018). It can also help circumvent other individual or institutional barriers, considering that higher levels of participation tend to promote a higher engagement in educational change processes (Cook-Sather, 2018).

Operationalizing a multistakeholder approach for GBL might be enhanced through co-creative processes, where the final playful artefacts effectively represent the experiences of all the participants.

5.4 Training

According to the empirical approach of García et al. (2022), teachers perceive that their training must be pragmatic and empower them with skills that enable their adaptation to diverse educational contexts, keeping them up to date with the most recent pedagogical interventions. These authors also acknowledge the relevance of teachers in the promotion of digital competencies, since training them is, in an indirect manner, ensuring that this knowledge reaches their students.

Sousa and Costa (2020) propose the application of GBL to teacher training, namely in the areas of digital competence and media literacy. The pedagogical premises of GBL of the use of failure as a motivational strategy or learning by doing can be effectively implemented to promote educators' media and information literacy skills. This is a less direct and possibly more cross-cutting impact for training than what the authors and studies in the SLR in this paper seemed to anticipate. Nevertheless, more informed and empowered teachers, families, educators, and other stakeholders for game-based pedagogical innovation could work as an important factor in promoting successful GBL interventions.

6. Proposing an Intervention Diagram

By reflecting on the different barriers and strategies presented above, the diagram presented in Figure 3 was created to support the development of GBL interventions.

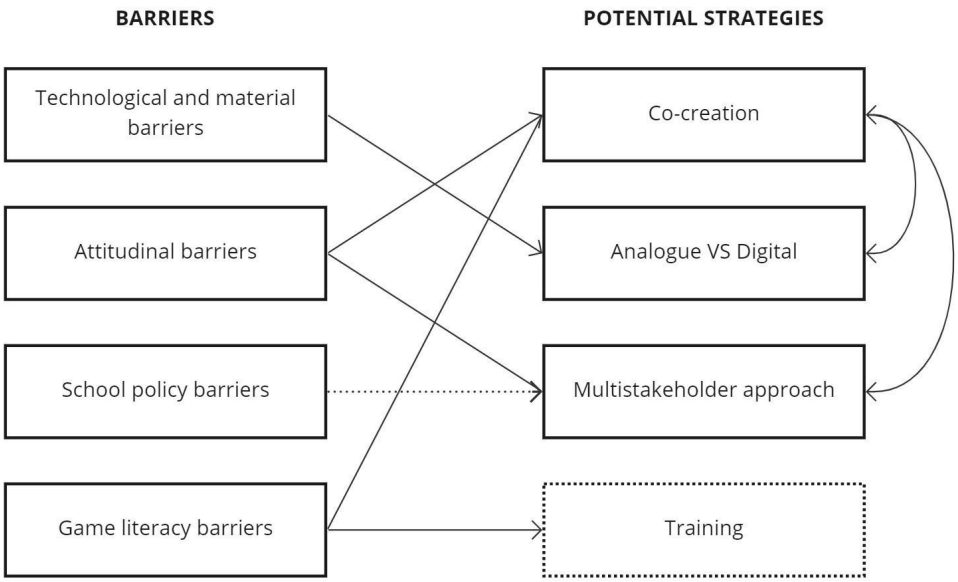

Figure 3: Proposed intervention model based on the barriers and strategies explored

This diagram provides teachers, educators, practitioners, or others with tangible advice on how to interrelate different concepts in the implementation of GBL interventions as follows:

- Through a detailed and early analysis of potential technological and material barriers in the context, some problems can be avoided. Namely, through an informed choice of analogue, digital, or hybrid games, depending on the technology, know-how, and funding available.
- Co-creation is meant to involve players as crucial agents in the creative process of games, understood in a more informed and positive manner, which impacts player attitudes and literacy;

- Ensuring that GBL interventions are multistakeholder fosters multilevel changes that bridge the attitudinal gap between educators, learners, and families, facilitating the implementation of innovative pedagogies;
- Indirectly, including policy-makers in these multistakeholder approaches can also support change and bridge the gap between them and the obtained results;
- Although in a game-based intervention, we cannot control the pre-training of those who participate, we must work to make the institutions aware of its importance and, when possible, provide it within the projects.
- Co-creative strategies also depend on a comprehensive analysis of the preferable technology for the implemented game – analogue or digital – since this will impact both the material conditions and the individuals' ability to participate in an equal manner.
- Because of its characteristics as a participatory and horizontal methodology, which allows the inclusion of several actors with the same level of involvement, co-creation appears aligned with the multistakeholder approach.

7. Conclusion

The present study aimed to identify the main obstacles faced in the implementation of GBL in educational contexts, and propose potential strategies to overcome these obstacles. The results of our systematic literature review revealed four main types of barriers: attitudinal and behavioural barriers, school policy barriers, technological and material barriers, and game literacy barriers.

Attitudinal and behavioural barriers refer to the reluctance of some teachers and students to use games for learning, either due to negative attitudes towards games or a lack of interest in them. School policy barriers refer to policies that restrict the use of games in the classroom, such as limitations on technology use. Technological and material barriers include a lack of resources and infrastructure to support the use of games in the classroom. Game literacy barriers refer to the lack of knowledge and skills needed to design, develop, and implement games for learning.

To address these barriers, potential methodological strategies were proposed, through an intervention diagram. These include the implementation of a co-creation and participatory-driven methodology that involves all stakeholders in the design and development of games. This approach promotes the creation of games that meet the needs and interests of the target audience and increase their engagement in the learning process. Additionally, an appropriate selection of analogue, digital, or hybrid games can help to address technological and material barriers as well as accommodate diverse learning needs and student preferences. The inclusion of different educational stakeholders in the process can also help to overcome attitudinal and behavioural barriers. Finally, promoting GBL training within projects can address game literacy barriers and provide educators with the necessary skills to implement GBL effectively.

This study's findings provide valuable insights for educators, policymakers, and researchers looking to implement GBL in educational contexts Further research is needed to test the effectiveness of these strategies and explore their potential to address broader educational issues.

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Mathematics and Sign Language Learning With a Tangible Game: An Inclusive Approach for DHH and Hearing Children

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Abstract: The purpose of this study was to investigate the potential of a tangible game, Inclusive Glossary of Mathematical Terms (GIM), to support the teaching of math and Portuguese sign language (*Língua Gestual Portuguesa*; LGP) to preschool and first-grade children, with an emphasis on inclusive education, knowledge acquisition, and engagement. GIM is composed of physical cards that are complemented by digital videos that run on an interface designed for this game. The game consists of two sets of cards and respective animations. As an inclusive math glossary, it also includes videos where concepts, characters, and objects are identified through images, words, and sign language. During the development process of GIM, it was possible to involve a multidisciplinary team, of which a Deaf sign language teacher and a sign language interpreter were part to ensure the clarity of the sign language and refine the written sentences accompanying the glossary. In order to validate its contents, a focus group of preschool and primary teachers specialized in the teaching of Deaf and Hard of Hearing (DHH) children was formed. A total of 120 children, aged between three and eight years old (M = 5.61; SD = 0.78), and seven LGP and special education teachers from three Portuguese schools participated in the study. The children used GIM in their classrooms, with the assistance of the participating teachers, who were subsequently interviewed to assess their engagement, interest, and learning outcomes. The interviews were analyzed using content analysis procedures, including descriptive statistics and Pearson correlations. The results indicated that GIM has the potential to effectively support the teaching of mathematics and LGP to preschool and first-grade children, especially in inclusive education contexts. The tangible nature of the game facilitated children's understanding of mathematical concepts and LGP, leading to improved involvement in the teaching-learning process. Moreover, the game promoted awareness of diversity and the principles of inclusive education, making it a valuable tool for promoting social inclusion and understanding. However, the study has reduced sample and context-specific limitations, suggesting a need for further research in this area.

Keywords: Game-based learning, Tangible game, Inclusive education, Mathematics, Sign language, Card game, Digital game

1. Introduction

There is still a lot of work to be done, in all areas of life, in terms of accessibility to eliminate the several barriers that people face when they are not met, such could be related to work, education, games, public services, etc. When we talk about the specific group of People with Disabilities and Deaf or Hard-of-Hearing (DHH) people the latter affirmation is even truer.

Considering that education is the foundation for the development of a person and their country, it must be accessible and inclusive to all people. Bearing in mind that different people have different needs, it is plausible to assume that different people will have different educational needs and so the educational system needs to be inclusive to meet the specific needs of each person. In the specific case of People with Disabilities and Deaf people, not having adequate education could lead, among others, to unemployment, lack of jobs, low income, and low communication skills. Communication is essential in everyday activities since it helps to create and maintain relationships, share experiences, express thoughts and feelings and learn (Wearmouth, 2016), so it is important to have high communication skills, which is only possible through inclusive education. Acknowledging the importance of inclusive education, the fourth objective of the Sustainable Development Goals (SDG) and the 2030 Agenda mention the importance of the right to inclusive and quality education (Granados et al., 2022).

Deaf people communicate with each other, essentially, through sign language, which is their native language. As such, teaching DHH children can be a challenge as it is inherent in teaching two languages, the sign language(s) and the written language of the country. It is noted that sign languages are the same as oral languages in the sense that both have their grammatical structure and rules and are used to communicate between people and their ideas and feelings, the only difference is that sign languages are visual-gestural languages, that is, the communication is through the use of gestures (signs) and visuality (Lacerda, Gràcia and Jarque, 2017).

Considering these premises, the current paper will focus on inclusive education, the use of Game-based Learning (GBL) in the early years of education, and how they can promote inclusive education and tangible games. The research will present the results of implementing the Inclusive Glossary of Mathematical Terms (*Glossário*

Inclusivo de Termos Matemáticos; GIM), which is a tangible game designed to support mathematics and sign language learning in classrooms.

1.1 Game-Based Learning and Tangible Games

GBL is an approach that leverages the motivational and engaging features of games to enhance learning outcomes (Plass et al., 2015). Games used for learning purposes have the advantage of creating a safe place for children, where they are not afraid to make mistakes, and that can provide them instant feedback – something that is of extreme importance in early education (Meyer, 2013). Games can also offer adaptive challenges and personalized learning experiences (Peirce, 2013) that cater to individual students' needs and diverse characteristics. Many studies have shown the benefits of GBL in improving learning outcomes in various subjects, such as science, engineering, and mathematics (Gao et al., 2020; Yu et al., 2022).

Tangible games are games that involve physical objects that can be manipulated and interacted with. In the specific case of GIM, the tangible objects are simultaneously game components and the user interface, framing it as a Tangible User Interface (TUI). One of the areas of application of TUIs is learning (Shaer and Hornecker, 2009), in the specific case of DHH children, who are visual learners, it could be advantageous to use TUIs in their learning process since it will allow them to touch what they are seeing digitally, it could also help children with motor disabilities through the use of the tangible parts. Essentially, it could help all children's learning process since the devices provide both physical and digital feedback which is important in early education (Meyer, 2013). As TUIs are used in a physical environment, it involves all senses of the child and as a consequence, it helps in their overall development (Shaer and Hornecker, 2009).

According to Shaer and Hornecker (2009), TUIs can benefit children with disabilities as they promote slower interaction, improve perceptual-motor skills, offer sensory experiences, facilitate collaboration, and empower children to have more control. This also suggests that TUIs offer greater opportunities for cognitive, linguistic, and social learning than exclusively graphical user interfaces.

1.2 Playfulness and the Learning Process: Mathematics and Sign Language

Mathematics is a fundamental subject in early education, and the development of mathematical skills is an important goal for preschool and first-grade students. However, mathematics can be a challenging subject for many students, particularly those with diverse learning needs (Schulte and Stevens, 2015). GBL has been found to be an effective way to promote the development of mathematical skills in young children (Cohrssen and Niklas, 2019). Tangible games have been shown to be particularly effective to this extent, as they offer opportunities for physical manipulation and interaction able to foster a deeper understanding of core mathematical concepts (Pires et al., 2019).

Language learning is one of the areas that is worked on in early education and its teaching and learning can be facilitated by GBL (Meyer, 2013). Most specifically, sign language implies the need for visual learning strategies – usually implemented in the classroom through images and pictures (Sousa et al., 2022) – that can be supported by the characteristics of both digital and analogue games as media. Moreover, both sign language teachers and special education teachers tend to acknowledge the pedagogical potential of games in the learning process, transversally to different curriculum subjects (Sousa et al., 2022).

1.3 Games and Inclusive Education

Inclusive education follows the social model which considers that disability only happens when there is a mismatch between the needs of the person and the environment that encompasses the person (Sousa et al., 2022). Therefore, it recognizes the diversity of students' needs and preferences and provides personalized learning experiences (Salgarayeva et al., 2021; Subban et al., 2022), similar to what GBL is able to do. Inclusive education also promotes social interaction and collaboration among students with different backgrounds and abilities, which can enhance their learning and social skills. Several authors also mention that inclusive education in the early years (preschool and kindergarten) is more effective than in the subsequent years of education (Bergen, 2003; Mallia-Milanes, 2017; Szumski, Smogorzewska and Grygiel, 2022).

GBL has been identified as a potential approach to the promotion of inclusive education, as it provides a fun and engaging way for students with diverse learning needs to access and interact with educational content (Sousa et al., 2022).

To implement a game-based strategy in an inclusive classroom it is crucial to ensure that the game is accessible. Accessibility in games relates to the design of the game being adequate to the needs of its players, whether they

are related to vision, hearing, motor skills, cognition, or any other (Cezarotto et al., 2022). In the specific case of the Deaf community, creating an accessible and inclusive game implies the integration of sign language videos, witch should take in consideration five dimensions: (1) cultural, where the participation of someone from the community is key for the game to be welcomed in the community; (2) educational, it is necessary that the sign interpreter understands the concept of what is translating; (3) psychosocial, the DHH person must trust on what is being translated; (4) semantic, sign languages have different semantics in relation to the spoken language, as such it might be hard to find the corresponding signs to translate, when that happens the interpreter might resort to fingerspelling; and (5) multimodal, sign language is usually done with the combination of facial expressions and signs and has its one grammatical structure, as such it could be hard to have an accurate translation of the material if not by someone 'real' instead of virtual characters, since the accuracy of the hand movements, location, and orientation, as well as the use of facial expressions, are crucial for conveying the message (Westin et al., 2022).

Considering the above-explored theoretical framework, based on the concepts of GBL, tangible games, and inclusive education, the present study aims to contribute to this body of research by investigating the potential of a tangible game (GIM) to support the teaching of math and Portuguese sign language to preschool and first-grade children.

2. Materials and Methods

2.1 The Tangible Game: GIM

2.1.1 General concept

GIM combines physical cards with digital videos that run on an interface specifically designed for this game. The current version of the game is composed of two sets of cards and respective animations: the drawing of numbers between zero and nine; ten actions related to localization terms (e.g., above, below, in front of, behind). As an Inclusive Math Glossary, it also includes videos where concepts, characters, and objects are identified through images, words, and sign language.

The concept of the game is based on the classic memory game in which the cards are placed face down and the player turns over two cards in turn to find the equal pair. If the cards turned over are the same, the pair is collected, if they are different, they are turned over again in the same place; the player who gets the most pairs right wins.

2.1.2 Content and interaction

The GIM version features matching cards that are related, but not identical. For example, in the set of cards related to localization terms, one card depicts an animal without any props, while the other shows the same animal in a position that illustrates the localization concept in question (e.g., a snake under a rug, or a mouse inside a fridge). Similarly, in the set dedicated to numbers, one card shows a representation of a number with human-like characteristics such as eyes and feet, while its pair displays the traditional representation of the number, with dashed lines and arrows indicating the "correct" way to draw it.

This logic of distinct pairs aims to encourage children at kindergarten age to create narratives and stories by using the game's elements. For instance, the isolated mouse depicted on one card is the same one that appears inside the fridge on another card. This design choice prompts children to ask questions and create stories around the images, such as "What is that funny mouse doing inside the fridge? How did it get there?" This approach helps foster children's creativity and imagination while also promoting their cognitive development.

Although these cards have stand-alone value, they are supposed to be complemented by short animations in video format that illustrate the concepts suggested in the card with props (e.g., a mouse inside the fridge). In the case of the localization terms set, there is a basic narrative that is based on the universal "hide-and-seek game" where the different animals represented in the cards and animations are hidden somewhere in the different rooms of a house. The video begins with a question mark that invites the child to anticipate the position of the animal in a static picture representing a room of the house that, after a few seconds, comes "to life" with movements of the hidden animal that eventually comes out of its hiding place revealing itself to the child.

In the numbers set, the animated video starts with a dot that will "draw" the number according to the direction indicated in the respective card and that, after reinforcement of the drawing direction by animated arrows, gives place to the fun "character number" represented in the card that completes the pair.

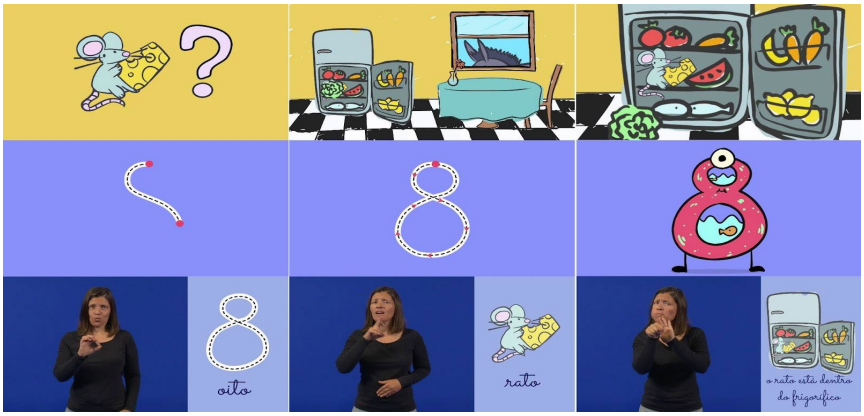

Figure 1: Video frames. Top row - sequence from the "inside" position; middle row - drawing of the number 8; bottom row (glossary) - number 8, partial sequence for "mouse is inside the fridge" (missing the frames of “inside” and “fridge”)

The animations are then associated with one of the cards in the pair, either animation of objects and characters (localization set) or drawing of numbers (numbers set), with the three dimensions of the inclusive glossary mentioned earlier (image, word, and sign language) related to the other card.

2.1.3 Interface

The videos mentioned before run on the interface that completes this game and is activated by inserting the cards into an open slot on the side. It is a triangular pyramid-shaped object, designed to be reproduced at low cost with laser cutting and 3D printing machines that are commonly found in so-called FabLabs. It integrates a screen, a camera, and a Raspberry Pi board that allows the playback of the respective video by reading the QR code engraved on one side of the cards. The project's output is to make the cutting plans, assemblies, codes, and video content available for free, to allow the reproduction of this game anywhere with access to the technologies and materials mentioned. In the implemented version, we chose to produce the cards and interface structure in 3mm MDF, for its low cost, resistance, and ease of machining with laser technology.

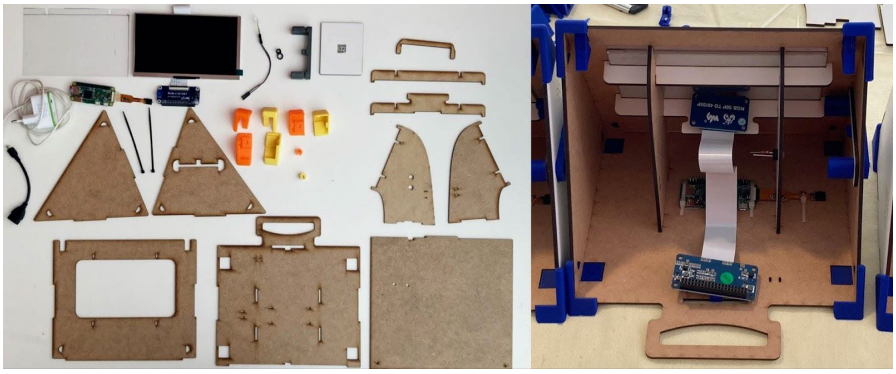

Figure 2: Pre-assembled interface components (left); inside view of the partially assembled interface (right)

2.1.4 Process

GIM's development process involved a multidisciplinary team, including a mathematician, an interaction designer, a psychologist, and a teacher who specialized in teaching the DHH. The team collaborated with a focus group of preschool and primary school teachers who specialized in teaching the DHH to validate the relevance of the content and the playful approach.

Following a sequential logic of intervention in the game development, the team developed the concept, narrative, interaction format, and content description. They also produced the visual proposal, including the design of characters, frames, and animation. A prototype of the interface was produced, and the feasibility of laser cutting and engraving was tested to produce the cards.

After validating the contents and illustrations with the focus group, the team moved on to the final production, which included the filming of sign language videos. A Deaf sign language teacher and a sign language interpreter joined the team to ensure the clarity of the sign language videos and refine the written sentences accompanying the glossary to avoid terms or grammatical structures that may cause confusion for DHH children.

Figure 3: Finished interface and cards (left); the partial set of cards in the finishing stage (right)

2.2 Participants

The study was conducted with the participation of teachers and students. Starting with teachers (*N* = 7), it is possible to divide them into two groups, preschool (*N* = 5) and first grade (*N* = 2) from three different schools. Additionally, of the teachers from preschool, there were teachers who did not know Portuguese Sign Language (*Língua Gestual Portuguesa*; LGP) (*N* = 3), who knew LGP fluently (*N* = 1), and a teacher of LGP (*N* = 1). The first-grade teachers did not know LGP.

With regard to students (*N* = 120), of which 75 were identified as males (62.50%) and 44 as females (36.67%), and their ages varied between 3 and 8 years old (*M* = 5.61; *SD* = 0.78), 101 were hearing students (84.17%) and 19 were DHH (15.83%) with no deaf parent (*N* = 0). Additionally, 12 (10%) had other special educational needs like autism (*N* = 6), functional diversity (*N* = 3), hyperactivity disorder, and attention deficit (*N* = 2), or were dependent on a Percutaneous Endoscopic Gastrostomy (PEG) to their nutritional needs (*N* = 1). It is also possible to divide them into different schools, school 1 (*N* = 9), school 2 (*N* = 9), and school 3 (*N* = 102), and different school years, preschool (*N* = 58) and first grade (*N* = 62). Schools 1 and 3 are mainstream schools whereas school 2 is a reference school.

2.3 Data Collection Instruments

To know the results from the implementation of GIM in their classrooms it was necessary to have four different interviews with the teachers (one with the teacher from school 1, two with each teacher from school 2, and one with all teachers from school 3) and to create two distinct documents that were sent to each teacher, one where they could characterize the students that participated in the study and other where they could annotate the date of the sessions, class, number of participants, and make observations that they considered relevant.

Moreover, for the interviews, it was used a semi-structured script that contained 18 questions to ascertain their opinions about the implementation of GIM (how it was used, the interaction that the children had with it), its advantages and disadvantages, the impact in the classroom and the learning process, as well as its potential improvements, in the inclusion of DHH children in education and in raising awareness in hearing children.

2.4 Procedure

Following the development process of GIM described above, we proceeded to conduct an empirical study with the support of LGP and special education teachers in three partner schools. For each school and its respective teacher, we provided detailed information on the use of the game and the data collection instruments. The game testing period was carried out between January and April 2022 in all three schools. A total of 54 test sessions were conducted during this period, with the participation of the individuals described in section 2.2.

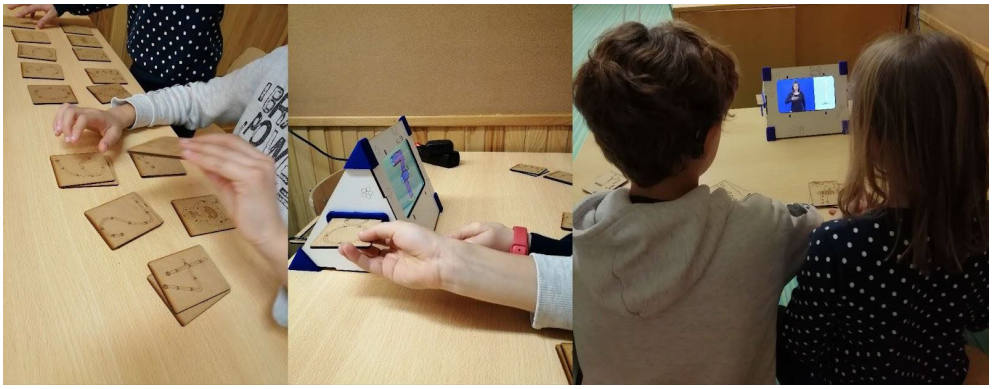

Figure 4: Children playing with GIM: 1) card pair identification; 2) card insertion in the interface; 3) video watching

All collaborating teachers were interviewed after this period in order to explore their experience of implementing GIM, with a focus on the above-defined research aim. The interviews were held via Zoom, and, with the explicit permission of the participants, recorded. They were then transcribed and coded using NVIVO software, where each sentence was considered a unit of analysis. The code used is listed below.

- General observations about the game
    - Game usage mode
    - Advantages of this pedagogical resource
    - Disadvantages of this pedagogical resource
    - Potential improvement points
    - Potential accessibility problems/lack of suitability for the target audience
    - Technical difficulties
- Game audience
    - Deaf children
    - Hearing children
- Children's attitude towards the game
    - Positive attitudes
    - Negative attitudes
- Identified needs
    - Creation of own resources
    - Additional existing resources
- LGP related aspect
    - Specificities of deaf children educational process
    - Deaf representativeness
    - Constraints to the implementation of the game
- Game Impact
    - Impacts on learning acquisition
    - Impacts on engagement
- Game Role on Inclusion and Awareness
- General positive attitudes toward the project

As mentioned above the analysis of the transcriptions was done using the NVIVO software, version 12, with 25.00% (one randomly selected focus group transcription) of the transcriptions being analyzed by two coders. The Inter Coder Reliability (ICR) was considered acceptable, with an average agreement rate between the two coders of 86.23%.

3. Results

Throughout the four interviews, the participants, when talking about the implementation of the game in the classroom and about the GIM project, addressed several topics, some more than others. The most discussed topics were the following: *Potential improvement points* (N = 81; 14.54%), mentioned in four out of the four interviews analyzed; *Game usage mode* (N = 75; 13.46%), mentioned in four out of the four interviews analyzed; *Advantages of this pedagogical resource* (N = 56; 10.05%), mentioned in four out of the four interviews analyzed;

Specificities of deaf educational process (*N* = 49; 8.80%), mentioned in three out of the four interviews analyzed; and *Disadvantages of this pedagogical resource* (*N* = 45; 8.08%), mentioned in four out of the four interviews analyzed. On the other hand, the topics that were least addressed throughout the four interviews were: *Hearing children* (*N* = 2; 0.29%), mentioned in two out of the four interviews analyzed; *Impacts on engagement* (*N* = 6; 1.08%), mentioned in one out of the four interviews analyzed; *Additional existing resources* (*N* = 7; 1.26%), mentioned in two out of the four interviews analyzed; *Constraints to the implementation of the game* (*N* = 8; 1.44%), mentioned in two out of the four interviews analyzed. These and other results are detailed in Table 1.

Table 1: Content analysis of the interviews' most coded nodes (557 coded units; 4 coded items)

Codes	Number of coded units *N* (%)	Number of coded items *N* (%)
1. General observations about the game	**311 (55.83)**	**4 (100.00)**
1.1. Game usage mode	75 (13.46)	4 (100.00)
1.2. Advantages of this pedagogical resource	56 (10.05)	4 (100.00)
1.3. Disadvantages of this pedagogical resource	45 (8.08)	4 (100.00)
1.4. Potential improvement points	81 (14.54)	4 (100.00)
1.4.1. Audience age	25 (4.49)	2 (50.00)
1.5. Potential accessibility problems/lack of suitability for the target audience	12 (2.15)	3 (75.00)
1.6. Technical difficulties	17 (3.05)	4 (100.00)
2. Game audience	**12 (2.15)**	**3 (75.00)**
2.1. Deaf children	10 (1.80)	3 (75.00)
2.2. Hearing children	2 (0.36)	2 (50.00)
3. Children's attitude towards the game	**52 (9.33)**	**4 (100.00)**
3.1. Positive attitudes	34 (6.10)	4 (100.00)
3.2. Negative attitudes	18 (3.23)	2 (50.00)
4. Identified needs	**20 (3.59)**	**4 (100.00)**
4.1. Creation of own resources	13 (2.33)	2 (50.00)
4.2. Additional existing resources	7 (1.26)	2 (50.00)
5. LGP-related aspect	**74 (13.29)**	**3 (75.00)**
5.1. Specificities of deaf children educational process	49 (8.80)	3 (75.00)
5.2. Deaf representativeness	17 (3.05)	3 (75.00)
5.3. Constraints to the implementation of the game	8 (1.44)	2 (50.00)
6. Game Impact	**34 (6.10)**	**4 (100.00)**
6.1. Impacts on learning acquisition	26 (4.67)	4 (100.00)
6.2. Impacts on engagement	6 (1.08)	1 (25.00)
7. Game role on inclusion and awareness	**38 (6.82)**	**4 (100.00)**
8. General positive attitudes toward the project	**16 (2.87)**	**3 (75.00)**

For further analysis, quantitative data from the content analysis was used to compare the perceptions of teachers of deaf and hearing children. Overall, data indicates the most expressive results for the sample of deaf children for all the analyzed categories, except: the *negative attitudes towards the game*, which were higher in the hearing children (*N* = 14; 77.78%), than in the deaf children (*N* = 4; 22.22); and the *impacts on engagement*, that were also only registered in the hearing group (*N* = 7; 100.00%). All the subcategories associated with LGP-related aspects were only registered in the sample of deaf children, which includes: *specificities of deaf children's*

educational process (*N* = 49); *deaf representativeness* (*N* = 17); and *constraints to the implementation of the game* (*N* = 8). Full results are presented in Table 2.

Table 2: Content analysis of the interviews' most coded nodes, by group (557 coded units; 4 coded items)

Codes	Deaf children *N* (%)	Hearing children *N* (%)
1. General observations about the game	**203 (65.27)**	**108 (34.73)**
1.1. Game usage mode	61 (61.00)	39 (39.00)
1.2. Advantages of this pedagogical resource	39 (69.64)	17 (30.36)
1.3. Disadvantages of this pedagogical resource	36 (80.00)	9 (20.00)
1.4. Potential improvement points	49 (60.49)	32 (39.51)
1.4.1. Audience age		
1.5. Potential accessibility problems/lack of suitability for the target audience	6 (50.00)	6 (50.00)
1.6. Technical difficulties	12 (70.59)	5 (29.41)
2. Game audience	**11 (91.67)**	**1 (8.33)**
2.1. Deaf children	10 (100.00)	0 (0.00)
2.2. Hearing children	1 (50.00)	1 (50.00)
3. Children's attitude towards the game	**24 (46.15)**	**28 (53.85)**
3.1. Positive attitudes	20 (50.82)	14 (41.18)
3.2. Negative attitudes	4 (22.22)	14 (77.78)
4. Identified needs	**16 (80.00)**	**4 (20.00)**
4.1. Creation of own resources	13 (100.00)	0 (0.00)
4.2. Additional existing resources	3 (42.86)	4 (57.14)
5. LGP-related aspect	**74 (100.00)**	**0 (0.00)**
5.1. Specificities of deaf children educational process	49 (100.00)	0 (0.00)
5.2. Deaf representativeness	17 (100.00)	0 (0.00)
5.3. Constraints to the implementation of the game	8 (100.00)	0 (0.00)
6. Game Impact	**20 (58.82)**	**14 (41.18)**
6.1. Impacts on learning acquisition	20 (74.07)	7 (25.93)
6.2. Impacts on engagement	0 (0.00)	7 (100.00)
7. Game role on inclusion and awareness	**22 (57.89)**	**16 (42.11)**
8. General positive attitudes toward the project	**16 (100.00)**	**0 (0.00)**

By analyzing the Pearson correlations, calculated through the similarity of the coded words by node and case, a dendrogram was elaborated, as presented in Figure 5. Through the mapping of the obtained correlations, it is possible to highlight the existence of several statistically significant correlations:

- The specificities of deaf children's educational process and the game audience (r = 0.98), as well as with LGP-related aspects (r = 0.95);
- The issues of deaf representativeness and the specificities of deaf children's educational process (r = 0.98);
- The identified needs in terms of additional existing resources and the audience's age (r = 0.97);

- The general positive attitudes towards the project and LGP-related aspects (r = 0.97), as well as with the specificities of deaf children's educational process (r = 0.95), and deaf representativeness (r = 0.94).

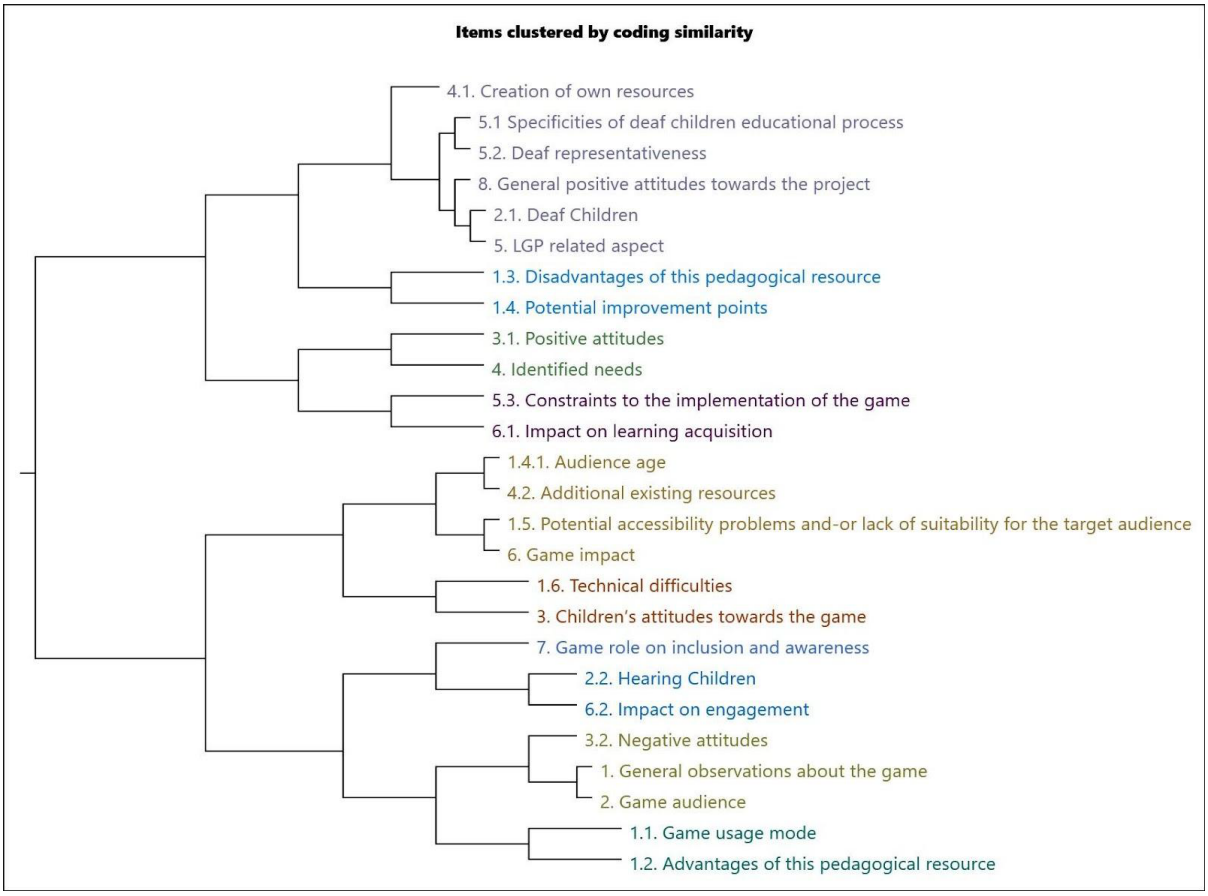

Figure 5: Dendrogram of Pearson correlations, by the similarity of the material coded in each case and node (557 coded units; 4 coded items)

4. Discussion

This study aimed to explore the potential of GIM, a tangible game, to support the teaching of mathematics and LGP to preschool and first-grade children. This study focused on analyzing the role of the game in the context of DHH and hearing children, emphasizing knowledge acquisition, involvement in the teaching-learning process, awareness of difference, and the principles of inclusive education.

The findings of this study indicated that GIM has the potential to support the teaching of mathematics and LGP to preschool and first-grade children. The tangible nature of the game made it easy for children to engage with mathematical concepts and LGP. The game provided a unique and interactive learning experience for the children that seemed to be aligned with the specificities of DHH children's educational process and needs.

GIM was found to be effective in promoting knowledge acquisition and involvement in the teaching-learning process. The game allowed children to engage with mathematical concepts and LGP in a fun and interactive way. Although these conclusions can be extended to DHH and hearing children, the impact on the acquisition of knowledge seems to be more salient in the first group. On the other hand, the game demonstrated a similar impact on the awareness of difference and the promotion of inclusion in both populations.

This approach was found to promote DHH representation and inclusivity by incorporating pedagogical resources such as sign language and a DHH adult in their instructional videos. This approach has been shown to be particularly beneficial for DHH children, as it enhances their educational experience in a way that is unique to their needs.

In conclusion, this study has shown that GIM has the potential to support the teaching of mathematics and LGP to preschool and first-grade children, particularly in the context of inclusive education. The tangible nature of

the game made it easy for children to engage with mathematical concepts and LGP, leading to greater knowledge acquisition and involvement in the teaching-learning process. Furthermore, the game promoted awareness of difference and the principles of inclusive education, making it an effective tool for promoting social inclusion and understanding.

4.1 Limitations and Future Directions

While this study has demonstrated the potential of GIM to support the teaching of mathematics and LGP to preschool and first-grade children in the context of inclusive education, there are several limitations to this research. Firstly, the sample size was relatively small, and the study was conducted in a specific cultural and linguistic context. Therefore, caution must be taken when generalizing the findings to other contexts, namely considering the different national legal frameworks of inclusive and deaf education. Additionally, the study did not assess the impact of GIM on learning outcomes in a direct manner, due to pandemic restrictions, but through the participating teachers. Further research is also needed to investigate the sustained effects of using the game in the classroom, through exploring its long-term impacts.

Future research in this area should focus on addressing the limitations of this study and exploring the potential of GIM in different contexts. Firstly, larger sample sizes and multi-site studies should be conducted to investigate the generalizability of the findings. Secondly, longitudinal studies should be carried out to assess the long-term impact of GIM on learning outcomes. Finally, future studies should focus on assessing specific learning outcomes achieved by using the game and exploring the potential of GIM to support the teaching of other subjects in addition to mathematics and LGP. Additionally, future studies could explore the use of GIM in other age groups or for children with different abilities, to further explore the potential of the game as an inclusive educational tool.

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The Novelty of Collaboration: High School Students Learning and Enjoyment Perceptions When Playing Cooperative Modern Board Games

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Abstract: Modern board games are changing the way people play analogue face-to-face multiplayer games. One of the novelties of this trend is the growing prevalence of games that offer collaborative gameplay. These cooperative games have been instrumental in shifting the demographic of players, attracting individuals who prefer engaging in constructive interactions rather than destructive confrontations. Likewise, playing cooperative games demand specific players' skills which can be associated with the concept of soft skills. Training these skills through modern cooperative board games, whether by modifying existing games or developing new ones as serious games or using gamification approaches, holds promising potential. To test the perception of students playing cooperative modern board games for the first time, we organized a one-day play session in a school environment, specifically in a classroom with the support of the students' teachers. Over a period of six hours (three in the morning and three in the afternoon), a total of 25 high school students from the vocational multimedia area, comprising students of all genders, participated in the session. The students engaged in gameplay with a curated selection of four cooperative modern board games. The results indicate that the students enjoyed the game sessions and recognized the significance of collaboration, as well as the associated skills including communication, empathy, organization, focus, and complementary interactions. The experiment reinforces the suggestion that the used modern board games could be introduced during classes as engaging activities fit for learning and training.

Keywords: Game-Based Learning, Board games, Cooperation, Collaboration, Education

1. Introduction

In today's digital age, young people are exposed to a variety of digital devices and online platforms that enable communication and social interaction. While these technological advancements have undoubtedly brought numerous benefits, there is a growing concern that they may be detrimental to young people's social skills, emotional development, and ability to form meaningful relationships. Therefore, endowing more collaboration, empathy, and face-to-face interactions in human relations, can be crucial for the holistic development of young people.

The case study presented in this paper aimed to investigate the potential of modern cooperative board games as a tool for developing soft skills in high school students, with a particular focus on collaboration. The study was conducted in a school environment, with 25 high school students from a vocational multimedia course. The selected games for the study were Team 3, The Mind, Rail Pass, and Magic Maze, chosen considering their cooperative nature, aligned with their accessibility for new players. The research focused on the students' perception of playing these games for the first time, their assessment of the level of collaboration, communication, difficulty, frustration, and enjoyment, and learning achievements from the gameplay. The study aimed to achieve a better understanding of the potential of these games as engaging activities for learning and training, and how they could be introduced in the classroom to enhance students' soft skills for work activities, namely collaboration, communication and expression during creativity and empathy collective tasks.

2. The Importance of Collaboration for Human Development

In the book "Moves in Mind: The Psychology of Board Games", Gobet et al. (2004) established parallels between the collaborative and cooperative processes that are triggered through board games and several concepts of developmental psychology, namely Piagetian theory. Piaget believed that children progress through four stages of cognitive development, with each stage building upon the previous one. In the first two stages (sensorimotor and preoperational), children's understanding of the world is primarily based on their own experiences. However, as they move into the concrete operational and formal operational stages, children begin to develop the ability to understand and think about abstract concepts, which requires collaboration and cooperation with others. In this view, collaboration and cooperation are particularly important in the development of social

understanding and moral reasoning (Vaish and Tomasello, 2013). This premise emphasizes the particular importance of decentration in board game psychology (Gobet et al., 2004). Decentration is a key concept in Piagetian theory that involves the ability to move beyond egocentrism and take into account the perspectives and actions of others (Kesselring and Müller, 2011). In the context of board games, decentration is critical to success (Gobet et al., 2004), as players must be able to consider the moves and strategies of their opponents and anticipate their actions.

As we can see, collaboration and cooperation are fundamental skills for human beings and play a crucial role in many aspects of our lives. Studies have shown that children prefer collaborative over individual food acquisition, indicating that motivation might be a key factor in the evolution of human-like cooperation (Rekers et al., 2011). Collaborative problem-solving (CPS) is a complex construct that involves both social and cognitive dimensions. The social dimensions of CPS include maintaining communication, sharing information, establishing shared understanding, and negotiating. The cognitive dimensions, on the other hand, include exploring and understanding, representing and formulating, planning, executing, and monitoring (Andrews-Todd and Forsyth, 2020). These skills are crucial in many fields, including education (Cimatti, 2016), business (Mitchell et al., 2010), and healthcare (Hariti et al., 2020).

Notwithstanding, Board games can help to support these relevant collaborative skills. Many games use specific game elements, like strategy and randomness, to simulate real-life experiences, that will favour the learning of these skills during the gameplay. Due to their particular characteristics, board games provide unique elements such as interaction among players, time invested in reading and interpreting rules between peers, which can help players to develop their collaborative and cooperative skills (Booth, 2021).

Through its international survey of board game players, Booth (2021) also demonstrated that "cooperation" appears as one of the favourite game mechanics, only surpassed by "worker placement". Cooperative games were also one of the favourite gaming styles of the 814 respondents, highlighting the relevance of exploring both collaboration and cooperation in the context of analogue gaming. Generating new forms of player interaction, without the need for aggressive conflicts and player elimination, are some of the traits of Eurogames (board games) (Woods, 2012). These Eurogames influenced the state of the art of board game design, where cooperative games thrive. Despite this potential, research regarding modern board games as game-based tools is still scarce (Sousa et al., 2023).

3. Collaborative Games and the Specific Case of Modern Board Game

3.1 3.1. Game Design Features to Deliver Collaborative Games

In the case of board games, cooperation is always present, even in competitive games. In multiplayer board games, explaining and following the rules constitute a form of collaboration among players (Rogerson et al., 2018). These analogue games lack automation systems to enforce the rules and the general gameplay (Zagal et al., 2006). The components serve as a medium for collaboration and require players to collaborate, as their disposal is how players interact with the game and with each other (Rogerson et al., 2016). Failing to fulfil these tasks can disrupt the game. Some players even express enjoyment in engaging with these bookkeeping tasks and interactions (Xu et al., 2011).

Some research has been conducted on the requirements and dimensions necessary to develop cooperative games. Seif El-Nasr et al. (2010) built up upon the work of Rocha et al. (2008). In addition to the need to introduce "Synergies between abilities", "Abilities that can only be used on another player", "Shared goals", "Synergies between goals", and "Special rules" (Rocha et al., 2008). Seif El-Nasr et al. (2010) add in their Cooperative Performance Metrics (CPMs) "Camera Setting", Interacting with the same object", "Shared Characters", "Special characters targeting lone wolf", "Vocalization" and "Limited resources". Some of these dimensions, such as camera settings, are specific to video games, while the emphasis on characters may not be as relevant in board games, as they often tend to abstract these types of entities (Pulsipher, 2012).

Seeking authors who focus more on the analogue dimensions can highlight how board games differ from other media. Zagal et al. (2006) defined four lessons regarding cooperative analogue games, highlighting the need to: have tension between individual utility and team utility; allow players to make decisions without the consent of the team; demonstrate the payoff of their decisions; and demand that players can use their special powers and abilities as ways to make a difference and assist the team. These lessons aim to address generic problems of cooperative games, like the disengagement of losing personal agency, being indifferent to the game outcomes and being controlled by an alpha player. The alpha player can be a form of emotional inaccessibility (Heron et al., 2018) because this indirectly excludes the other players from the game. Duarte et al. (2015) directly

addressed these problems and sought to identify distinct features of games that generate cooperative experiences, whether it be teams competing with each other or. These distinctive features focus on team dynamics and highlight the game's defeat condition, as players can lose as a team against other players or collectively against the game system. Additionally, the authors emphasize the importance of information, including how the game state is presented to the players and how the player can communicate. The focus on information was recognized by Sfikas and Liapis (2020) when they tried to implement an IA agent to play Pandemic (2010), discovering that there was a need to create a way to visualize the information and the communication between humans and non-humans in the game to foster collaboration. Yuan et al. (2021) identified similar requirements for playing board games in online environments, highlighting the need for additional methods to compensate for the lack of communication through informal channels. Social behaviour, physical and other indirect communication need new channels for these games to be played online. Later, Zagal (2020) updated his lessons and pitfalls regarding collaborative games, highlighting the need to control information (private and collective). Zagal also argues that trust is crucial in a collaborative game because it is necessary for optimal play from both a teamwork perspective and the individual taskwork associated with players' individual actions.

We propose to select modern board games with the previous features. Playing them with students as ways to deliver collaborative experiences, evaluating if the students can identify the generic requirements for collaboration. In this way, we aim to test whether these games could be included in the school curriculum as tools for learning about collaboration, exploring their advantages, disadvantages, and potential pitfalls, all while fostering the development of new skills.

3.2 The Evolution of Modern Collaborative Board Games

Despite the declared collaborative characteristics of analogue games, fully cooperative games are becoming increasingly popular. Board Game Geek (BGG) identify the first cooperative game as 50 Card Games for Children (1933). After this game, BGG identifies 10.060 other games and expansions associated with the category of Cooperative Game. Considering only the games for 2023 and beyond, 650 new games fit into this category. As Zagal (2020) states, some popular games delivered collaborative experiences before, but The Lord of The Rings (2000) by Reiner Knizia was the game that proved that cooperatives could be successful. This game won the Spiel des Jahres in 2001 and inspired Pandemic (2008), one of the most popular cooperative board games ever made.

The variety of modern cooperative board games is vast. There are games of all types, themes, complexity, duration and cost. Games both for children and adults. Two cooperative games have achieved the top 1 of best games at BGG. Pandemic Legacy: Season 1 (2015) was number 1 between 2016 and 2017, while Gloomhaven (2017) dominated from 2017 to 2023. These are two examples of complex games, usually played by hobbyist adult players, as BGG tends to exhibit bias and favour high scores for such games.(Samarasinghe et al., 2021). However, several other popular games have achieved notable success. For instance, Hanabi (2010), Just One (2018), and The Crew (2019), won the prestigious Spiel des Jahres prizes. The Mind (2018) was also one of three nominees for 2018. Additionally, games like Sleeping Gods (2021) ranked high on the lists of acclaimed board game connoisseurs and influencers of 2021.

The variety is immense. We argue that these cooperative, or fully collaborative games expand upon the characteristics of Eurogames. In a simplified approach, Eurogames flourished in Germany from the 1980s to 1990s, characterized by controlling the conflict between players and avoiding player elimination (Woods, 2012). Eurogames enhanced the design elements of the contemporary cooperative game. As Eurogames became popular and their design features spread worldwide, new collaborative interactions emerged in games.

3.3 Characteristic of Cooperative Modern Board Games to Learn About Collaboration

Based on the requirements mentioned in the previous subsections, it is possible to find games classified as "Cooperative games" among the top BGG games that can be utilized in a school environment, such as a classroom. Previous experiences proved that the games must be simple and fast to play, requiring less effort from teachers and facilitators to teach the rules and allow students to play more than once to fully explore the game (Sato and Haan, 2016; Sousa, 2020, 2021). This is why it is recommended for a class from one to two hours to play games that do not exceed 30 minutes and with complexity below 2.00 (according to BGG, range from 1 to 5). According to player profiles and preferences, For higher engagement, it is recommended to select games that offer experiences capable of captivating players who enjoy problem-solving, exploring narratives, and the opportunity to create and build new and imaginative elements during gameplay. (Martinho and Sousa, 2023;

Zagalo, 2020). For practical reasons, each game should allow 4 to 8 players, which demands fewer facilitators to teach and collect data, and fewer copies of the same game (Sousa and Dias, 2020; Sousa, 2021).

4. Methodology

4.1 Sessions and Data Collection

The sessions occurred during a morning and an afternoon day. The students were divided into groups of 4 to 6 players. We established a dedicated table per game with an assigned facilitator responsible for teaching the game, addressing doubts during the gameplay, taking notes and asking questions after the play sessions. The facilitator had a form to guide them. The form (A4 sheet of paper) was divided into five sections.

1. Section 1: General notes.
2. Section 2: A table with a Likert scale from 1 to 5 for the players to classify (simultaneously with their fingers) the following game levels: Collaboration; Communication; Difficulty; Frustration; Fun.
3. Section 3: question "What did you enjoy more about the game?".
4. Section 4: question "What did you enjoy the least in the game?".
5. Section 5: question "Did you learn anything by playing the game?".

The questions from sections 3 to 5 were set to generate discussion and allow the facilitator to establish a debriefing process with the players, conducting them to reflect on the purposes of playing the games. During debriefing, players should have the autonomy to reflect, discuss and create significance for the activity (Sousa, 2021; Crookall, 2006).

After playing and debriefings, the students rotated tables and played different games. This process allowed every student to play all the games several times, while also providing an opportunity for the facilitator to practice conducting the games.

4.2 Game Selection

To maximize the number of different games as possible during a six-hour session involving 25 students, and to allow for repeated plays to enhance play efficiency, we selected games with low complexity and fast gameplay. This choice was primarily driven by the need for students to quickly grasp the rules before engaging in gameplay.

Table 1: Characteristics of the selected games

Game	Complexity	Duration	Number of players	Core collaboration dynamic
Hanabi	1.69	25	2-5	Players see their teammates' cards but not theirs. Players can give clues to teammates for them to play cards in a sequence.
Magic Maze	1.77	15	1-8	Players can move pawns in one direction or do specific tasks. The pawns must travel through the maze, requiring all players to move them.
Raill Pass	2.00	10	2-6	Players handle trains with cubes, passing them to get the cubes of their colour to their train station. During the game, players will have more trains than hands and places to pack them.
Team 3	1.10	30	3-6	A team of 3 players communicate to build a pattern with Tetris pieces. Sound and vision communication is limited.
The Mind	1.08	20	2-4	Players play cards in a collective crescent sequence without knowing what the other players' cards are. Communication is forbidden.

While the selected games may have reduced complexity compared to the top-rated BGG games, they still offer ample challenges for the players. They demand collaboration, and all players win or lose together. All games have design elements that constrain the alpha player effect, mostly due to the way the games deal with information (Duarte et al., 2015). Communication is limited or hidden in some way. In Rail Pass, communication is indirectly limited because there is not enough time for a simple player to process all the information due to the time limit and the need to deal with the train operation at the rail station. This complexity and game state changes serve as methods to conceal information. Because we are dealing with analogue games, the use of the

game's physicality is important (Rogerson et al., 2016). Even in games like The Mind, which involve minimal physical actions, players need to use their arms to signal pauses and utilize help cards, requiring motor coordination among players. Almost every selected game is played in real-time, adding tension to the gameplay and preventing perfect planning. While players can strategize, they must trust their teammates' taskwork like Zagal (2020) recommended. Games like Hanabi, Team3 and The Mind do not have this dimension. However, it is easily introduced as a modding approach to adapt the game (Sousa, 2021). In our case, we defined a limit of time which guaranteed that all the students could play all the games several times. Considering also the recommendation from Duarte et al. (2015), we introduced loss conditions to Rail Pass, meaning that scoring below a predetermined value was considered a failure.

Table 2: Identifying the characteristics of the game according to the game design features recommended for collaborative games

Game	Information		Challenge and tension		
	Communication limits	Hidden information	Physical constraints	Real-time	Lose conditions
Hanabi	1	1	1	*	1
Magic Maze	1	1	1	1	1
Rail Pass	*	*	1	1	*
Team3	1	1	1	*	1
The Mind	1	1	*	*	1

*Indirect relationships or game adaptation

5. Results and Discussion

5.1 Quantitative Data

For the purposes of statistical analysis, each player's participation in a game session was counted, with a total of 113 participations, spread across the 23 sessions. Hanabi was the most played game, being played by 29 different people, followed by Magic Maze (*N* = 26); Team3 (*N* = 25); The Mind (*N* = 23); and Rail Pass (*N* = 10).

Considering players' self-perception, the data obtained indicated that the level of fun was the most prominent factor (*M* = 4.82; *SD* = 0.59), followed by collaboration level (*M* = 4.50; *SD* = 0.86), communication level (*M* = 3.64; *SD* = 1.21), frustration level (*M* = 3.59; *SD* = 1.49); and difficulty level (*M* = 3.09; *SD* = 1.26). When analyzing the variables separately for each played game, further nuances were discovered, as presented in Table 3.

Table 3: Self-Perceived collaboration, communication, difficulty, frustration, and fun levels experienced while playing each game (*N* = 113)

Game	Magic Maze		Hanabi		The Mind		Rail Pass		Team 3	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Collaboration Level	4.23	1.03	4.38	1.02	4.39	0.84	4.80	0.42	4.92	0.28
Communication Level	3.58	0.81	3.83	1.14	2.70	1.43	4.10	0.57	4.16	1.18
Difficulty Level	3.04	1.12	2.72	1.10	3.70	1.85	2.70	1.06	3.16	0.80
Frustration Level	4.38	0.80	3.55	1.57	3.78	1.62	3.00	1.49	2.72	1.40
Fun Level	4.69	0.97	4.79	0.49	4.91	0.29	4.60	0.70	5.00	0.00

According to Table 3, the level of fun was the most prominent for every game except for Rail Pass (*M* = 4.80; *SD* = 0.42), in which collaboration was the highest-rated aspect of the experience. Team3 was classified as the game in which collaboration was deemed crucial (*M* = 4.92; *SD* = 0.28), and also as the most challenging one (*M* = 3.70; *SD* = 1.85). Frustration was reported most frequently after playing Magic Maze (*M* = 4.38; *SD* = 0.80).

Table 4: Pearson correlations among self-perceived collaboration, communication, difficulty, frustration, and fun levels (*N* = 113)

Variables	Communication Level	Difficulty Level	Frustration Level	Fun Level
Collaboration Level	*r* = .34; *p* = .000	*r* = .05; *p* = .604	*r* = -.22; *p* = .018	*r* = .23; *p* = .013
Communication Level	-	*r* = -.07; *p* = .445	*r* = -.26; *p* = .005	*r* = .07; *p* = .447
Difficulty Level	-	-	*r* = .36; *p* = .000	*r* = -.11; *p* = .238
Frustration Level	-	-	-	*r* = -.04; *p* = .680

By calculating a Pearson correlation between the variables, it was possible to analyze the strength and direction of the linear relationship between them (Table 4). Through this process, five statistically significant correlations were identified (setting the level of statistical significance at 0.05 or below). Collaboration level was found to have a significant and positive correlation with the level of communication (*r* = .34; *p* = .000), as well as with the level of fun (*r* = .23; *p* = .013). This indicates that as one variable increases, the other variable also tends to increase. Similarly, a significant and positive correlation was observed between the level of frustration and the level of difficulty (*r* = .36; *p* = .000). On the contrary, the level of frustration showed a significant and negative association with the level of collaboration (*r* = -.222; *p* = .018) and the level of communication (*r* = -.26; *p* = .005). This suggests that as one variable increases, the other variable tends to decrease.

5.2 Qualitative Data

For each play session with different groups, the facilitators who taught the game and supported the gameplay filled out a form sheet. Drawing inspiration from grounded theory (Charmaz, 2008), we analyzed the general notes on the play session and the answers to the players' responses to questions posed by the facilitators regarding what they enjoyed most, and least, and what they learned from playing the games.

After analyzing all the facilitator notes using ground theory based-analysis, we identified three different clusters that consistently emerged in response to questions about each play session:

- Game design (1).
- Game experience and indirect results (2).
- Player agency and direct interactions (3).

Table 5: Example of the clustering and definition of clusters (Grounded Theory)

Form question	Example of Collected notes	Example of dimensions (clusters)				
Facilitators' general notes	Engagement. Some discussions (when a player did a reckless move).	Engagement (2)	Individualism (2)	Communication (2)	Discussion (3)	Strategy (3)

Form question	Example of Collected notes	Example of dimensions (clusters)				
What did you enjoy more about the game?	The game is fun even though there is high frustration. Players want to play again.	Engagement (2)	Difficulty level (1)	Challenge (2)	Fun (2)	Stress (2)
What did you enjoy the least in the game?	Tracking. Hard to communicate . Using the red pawn was aggressive.	Communicatio n (3)	Player Behavior (3)			
Did you learn anything by playing the game?	Collaboration, communicatio n and patience (control frustration and be patient with teammates).	Cooperation (2)	Avoid recklessnes s (3)	Empathy (3)	Communicatio n (3)	

Table 5 shows examples of how the facilitator notes were linked with generic dimensions of the play experience, with each dimension categorized into clusters (in brackets). Although the potential subjectivity of this analysis, as the type of note was based on what the facilitators considered important, it reveals patterns about the games to complement the quantitative analysis.

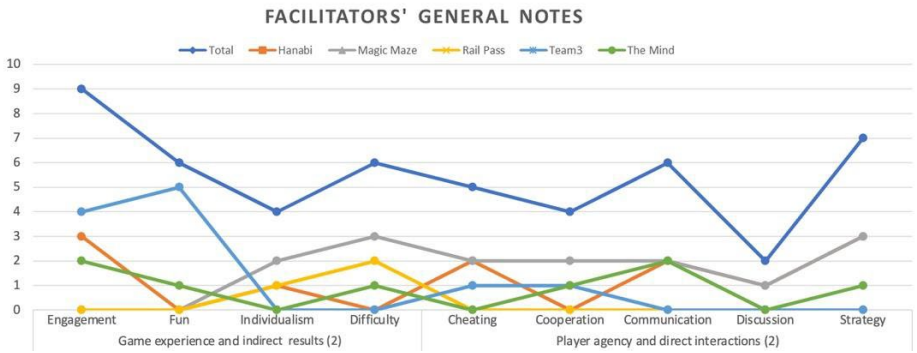

Figure 1: Quantity of dimensions (and clusters) associated with each game regarding the facilitators' general note

Figure 1 highlights the modern board game dimensions of the selected games. The strategic dimensions were highly prominent, and the engagement dimensions also received high ratings. Students expressed liking playing the games in this context and displayed motivation throughout the sessions. Team3 appeared to have the most significant impact on players, followed by Hanabi. Magic Maze and Rail Pass were perceived as the most challenging games, which is coherent with the higher level of complexity according to BGG (Table 1).

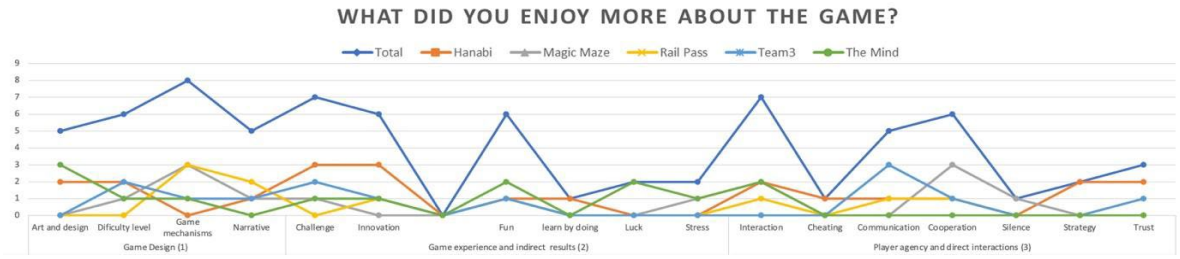

Figure 2: Quantity of dimensions (and clusters) associated with each game regarding the question: "What did you enjoy more about the game?"

Magic Maze, the most challenging game (Figure 2), exhibited higher levels of cooperation dimensions. Team3, which necessitated alternative forms of communication, showed greater communication dimensions in the responses. Fun dimensions were observed across all games despite The Mind having more reactions. Players emphasized Hanabi as having more challenging dimensions, which contrasts with the facilitators' notes that associated these dimensions more with Magic Maze. Rail Pass and Magic Maze are games that try to simulate a theme, whereas the others are more abstract. Players perceived these two previous games as having more intriguing game mechanisms. It suggests that there is a relationship between complexity, challenge, and simulation.

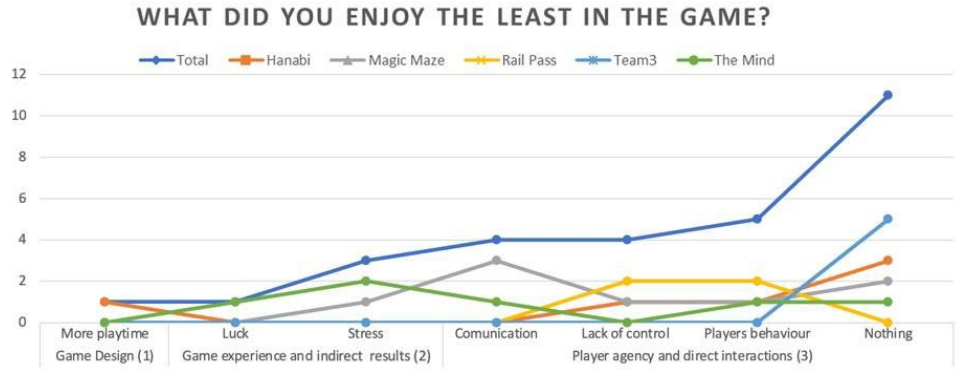

Figure 3: Quantity of dimensions (and clusters) associated with each game regarding the question: "What did you enjoy the least more about the game?"

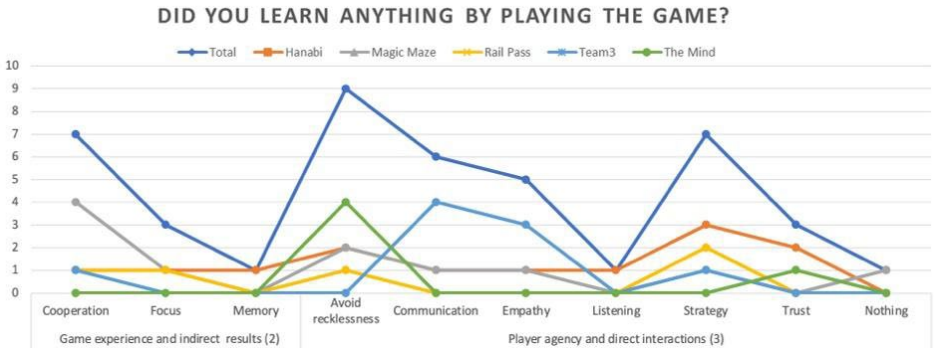

Figure 4: Quantity of dimensions (and clusters) associated with each game regarding the question: "Did you learn anything by playing the game?

The players' perceptions associated with what they liked the most (Figure 2) and what they learned during the game (Figure 3) align with communication in Team3, strategy in Hanabi and cooperation in Magic Maze. The high mention of avoiding recklessness in The Mind can be attributed to one of the game's challenges and player actions: knowing when to play your cards.

We would like to highlight a comment from Hanabi session 3, where the facilitator wrote: "Finding ways to cheat leads us to cooperate and communicate in a fun and complex ways". The facilitators' notes revealed five associations with cheating (Figure 1). It appears that the game rules, particularly when they restrict communication, lead to cheating, which adds humour and fun to the experience. The players' responses about

what they enjoyed most (Figure 2) indicate high levels of fun statements and challenges, which are related to interaction, cooperation, and communication.

The limitation of communication and stress is apparent in the responses indicating what players enjoyed less (Figure 3). In response to the final question regarding what players learned from playing the game, several dimensions emerged, including the significance of empathy, trust, and avoiding recklessness. The findings underscored the importance of establishing effective communication and cooperation to overcome the game's challenge (Figure 4).

6. A Framework to use Games That Generate Learning About Collaboration

The case study enabled us to develop a framework for teachers, educators and trainers who intend to incorporate board games (and games in general) into learning activities that promote collaboration among students and help them identify the necessary requirements for effective collaboration. These generic requirements draw inspiration from Habermas' communicative rationality theory, which is applied to game rules and structures that require player agency and guide players towards predefined experiences in order to promote communicative rationality (Niemi, 2005; Rienstra and Hook, 2006). Although communicative rationality does not consider the playful dimensions, in the case of board games, the generative dimension of rules transforms restrictions (rules) into new ways of expression (Calleja, 2022). Through game mechanics, players follow pre-established rules. Game mechanics frame players' agency, transforming inputs into outputs, and generating feedback and new game results. The games must not only allow players to make decisions but also provide a framework for efficient communication, equality of power, shared goals and building trust that leads to collaboration experiences. To apply these concepts to game selection and address collaboration in a specific context, we propose the following process (Figure 5).

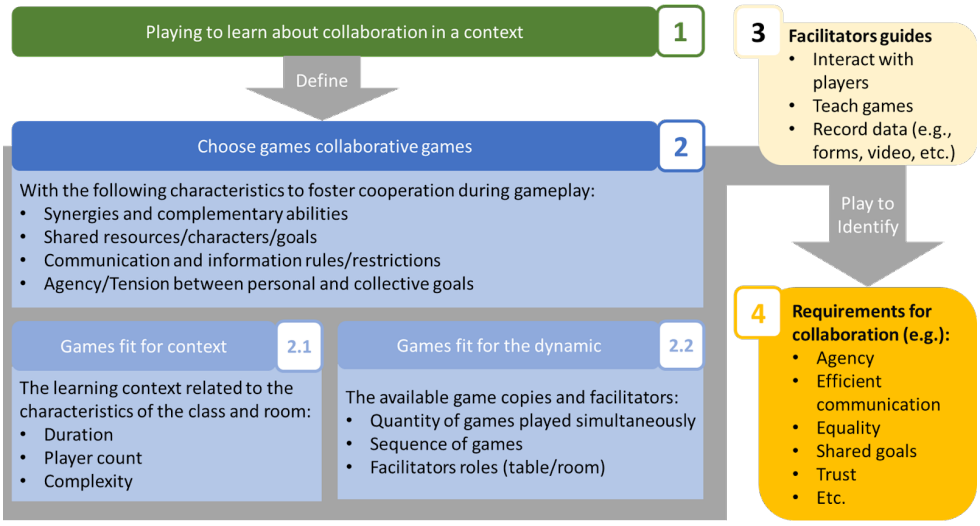

Figure 5: Process to select games and game features that lead to learning about collaboration

The process illustrated in Figure 5 requires agents (e.g., teachers) to define the context to address collaboration (1). In the case study, it was an initiative in a school that took place over the course of an entire day, but it could have been a class or sequence of classes on different days. After defining this, the agent determines which games to use that must have specific characteristics to generate collaborative experiences (2). The game choices must take into account other practical information like the available time, number of participants, the room and how many facilitators are available to support the game (or games). The play requires player agency, but only when the players know how to play. This tutorial part is the facilitator's role (the same as the agent or not). The facilitator must define a way to record data to evaluate if the players achieved the goals. In this case, it involves assessing whether the players had collaborative experiences because the game might fail due to the uncertain nature of games and player behaviour (Costikyan, 2013). This process is comparable to a serious game where the purpose is to learn about collaboration.

Our proposal departs from having games to choose from, instead focusing on designing new games. The newly designed games must incorporate collaborative characteristics (2). However, the gameplay itself involves a playtest process that requires continuous play until the game development finishes (Schell, 2008). Once the game is finalized, it can be used in a context to learn about collaboration.

7. Conclusion

In conclusion, this study provides valuable insights into the potential of modern cooperative board games as a tool for developing soft skills in high school students, with a particular emphasis on collaboration. The research findings indicate that the chosen games, namely Team3, The Mind, Rail Pass, and Magic Maze, were effective in enhancing students' collaboration, communication, and problem-solving skills. Moreover, these games were found to be engaging and enjoyable for the students. The results suggest that incorporating these games as engaging activities in the classroom could enhance students with soft skills.

The quantitative data analysis indicated that the fun level and collaboration level were the most prominent aspects of the play experience. Increasing cooperation is associated with increasing collaboration, while communication level and frustration level received lower scores. Additionally, the qualitative analysis revealed that the game design, game experience, and player agency were the three clusters consistently observed in all questions regarding each play session.

The facilitators' notes complemented the quantitative analysis and revealed patterns regarding the games, including the relationship between complexity, challenge, and simulation. The players' perceptions aligned with what they liked the most and what they learned during the game matched for communication in Team3, strategy in Hanabi, and cooperation in Magic Maze.

Cheating emerged as a noteworthy topic, leading to humour and fun, especially when the game's rules limited communication. The study has demonstrated the substantial impact of modern board games have a significant impact on players, fostering empathy, communication, cooperation, and strategy.

Furthermore, the present study contributes to the growing body of research on analogue game-based learning in education and highlights the potential of modern cooperative board games as a pedagogical tool. By providing evidence of the benefits of using such games in the classroom, this study encourages educators to consider incorporating them into the teaching practice. However, we did not test using only one game (with several copies) simultaneously played by all students during a class and facilitated by a single teacher. This approach would typically be the standard way to use the games in classes. To make this feasible, the teacher would need to create support material to instruct all students in the game (e.g., video presentation, player aids, etc.). Despite the positive results, it is unlikely that teachers would use the game without a connection to the established curricular content. This limitation requires more game and curricular adaptation. Another possibility is to transform the play session into parallel school activities, such as board game clubs located in school libraries or other social interaction spaces within the school. In such settings, a facilitator could provide support for game usage. Future research and experimentation could examine the outcomes of implementing these solutions.

Overall, this study aimed to achieve a better understanding of the potential of modern cooperative board games as engaging activities for learning and training. The results strongly suggest that these games have significant potential in enhancing students' soft skills. Future research could further investigate the long-term impact of introducing modern cooperative board games in the classroom, particularly with diverse and larger samples, focusing on the development of soft skills. Conducting a longitudinal study would be valuable to assess the effects of playing these games over a more extended period and to determine whether the skills learned during gameplay are applicable to real-world situations.

Acknowledgments

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Chances and Limitations of Immersive Augmented Reality for Game-Based Learning in Museums

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Abstract: This article discusses opportunities and limitations of using immersive augmented reality (AR) with head-mounted displays for gaming and education in museums. We first report on a prototype application for HoloLens 2 that we developed and tested with 109 museum visitors in a recent project for an exhibition with large animal skeletons. The results show that the feedback from visitors was overall positive, while more steps are needed before it can be implemented in a museum routine. Based on the findings, we discuss hypotheses for the planned further development of the approaches towards game-based learning in the real environment of a natural history museum.

Keywords: Augmented reality, Head-mounted display, Location-based games, AR in cultural heritage

1. Introduction

In recent years, there has been an increasing interest in developing Augmented Reality (AR) applications for museums. While mostly these are running on handheld devices owned by visitors who bring them along to the museum, not as many applications have been developed for head-mounted displays (HMD) that allow immersive experiences for individuals. Application development for HMD-based AR so far has more taken place targeting the engineering industries such as for maintenance and construction, to be used by professionals who get trained. In museums, however, visitors as laypersons without any training would need to learn how to use these devices first (Liu et al. 2021). Moreover, application scenarios are not yet well established and development needs to start with designing use cases. Thus, with the aim of developing usable applications in this area, we entered an indeterminate field with new challenges in defining customer needs, previously unknown interaction patterns and application ideas in a team of developers, designers and curators.

In the recently completed project presentXR (2023), after developing an authoring pipeline (Rau et al. 2022), we developed a first AR prototype application for head-mounted displays (Microsoft HoloLens 2) that augmented an existing animal skeleton exhibition with digital information, and finally tested it with over 100 museum visitors. We are continuing our work in an EU-funded project LoGaCulture (2023) with the aim of applying these technology experiences and insights to locative learning games for cultural heritage in general. We therefore discuss in this paper how our initial findings from the previous experiment lead to future expectations for game-based learning in museums, particularly by focusing on immersive AR with head-mounted displays that enable increased levels of presence-based feelings. In the following, after looking at the most important related work, we first summarise our prototype to date and the main evaluation outcomes. Based on these results, we hypothesise about the potential of the technology for application to games and, in particular, to game-based learning in a museum.

2. Related Work on Immersive AR Games in Museums

The perception and expectation of museum visitors have shifted (Macdonald 2007): While visitors have so far been perceived mainly as a passive mass, museums are increasingly realising the potential of viewing visitors as active individuals or groups. A study by Sheng and Chen (2012) showed that visitors usually seek easiness and fun, cultural entertainment, personal identification, historical reminiscences, and escapism. Gamification is a recent means to address active visitors. Paliokas and Sylaiou (2016) already noticed a growth of serious games applied in different kinds of museums. They also found that the most used interaction styles based on a classification by Djaouti et al. (2011) in these games is moving around, followed by selecting and matching. Less frequently used interactions are shooting and destroying. They found that although their systematic mapping approach could not identify general learning goals for museums that are best addressed with games, there may be high acceptance rates due to other criteria than learning. The collected 'gamified' application examples could

be classified into the two categories "game" or "play", with differences in whether there are strict rules and clear goals in the game type, or more freedom in the play type (Djaouti et al. 2011; Paliokas and Sylaiou 2016).

Especially location-based mobile applications are used in museums. For example, Spierling and Kampa (2017) described a system for a location-based AR storytelling experience in a Roman fort where visitors can use tablets to meet ghosts of the historical inhabitants who remember what it was like to live in this place in Roman times. It was evaluated how the app can support the sense of presence in terms of a historical aura of this place (Spierling et al. 2017). Feelings of presence and immersion appear to be important for cultural heritage projects (Pujol and Champion 2012). Marto and Gonçalves (2022) provided a systematic review of presence assessment in AR games and found a link between the sense of presence and engagement, which we consider an important goal for museum exhibitions.

Immersion is often connected to digital add-ons of an exhibition, such as Virtual Reality (VR) or AR applications (Harkvoort 2013). Bitgood (1994) highlighted that immersion is useful to achieve a sense of realism and already linked immersion to interaction, environmental feedback and multisensory stimulation, stressing the importance of adding VR or AR games or experiences to exhibitions to enhance visitor immersion. Komarac and Došen (2020) found that aesthetics support immersion more than interactive technology.

Hammady et al. (2016) have explored gamification in combination with AR. Based on their identified communication model, information about the exhibition is selected by curators or other museum staff, then coded into an AR app by developers and at the end de-coded by users. Furthermore, they found that incorporating game elements into the AR experience provides a mechanism for enriching the educational value of an exhibit. In light of these findings, the authors have created a gamified and immersive AR application specifically tailored for use in a cultural heritage museum (Hammady et al. 2020).

In recent years, AR applications for museums have grown in number and have been documented in literature reviews such as by Boboc et al. (2022). They analysed 1201 papers on the topic of AR in cultural heritage in the last ten years. However, most AR experiences are smartphone-based. Creating experiences for HMDs such as the HoloLens is still novel and not yet many examples exist, e.g. by Hammady et al. (2020). Another example demonstrated by Giariskanis et al. (2022) is an application built for the HoloLens, using hand tracking, voice commands and spatial audio to enhance the visit at a local cultural heritage site.

In summary, game-based applications for head-mounted display-based AR are still rare and in a state of research prototypes. Similar, in our work of the presentXR project, we pursued the goal of developing an AR application that shows additional information, explanations or elements that would otherwise not be observable directly on existing real exhibits in order to visualise the invisible. Our prototype was intended to be interactive, to engage active visitors and to enhance not only their immersion in digitally added content, but also their sense of presence in the physical exhibition itself (Bitter et al. 2022). This is subsequently to form the basis for serious games on museum content, which we hope will increase engagement.

3. Immersive Augmented Reality Example Application

3.1 Project aim

The aim of the development team of the applied research project presentXR (2023) was to demonstrate the creation and implementation of presentations for exhibitions using augmented reality (AR) technologies to provide a future-oriented experience for a museum. By creating a cross-reality (XR) as a fusion of real and virtual spaces, participants should have the feeling of being (co-)present in the real world with digital elements and be able to experience virtual content through the use of head-mounted displays. From the very beginning, we have geared development towards the immersive Microsoft HoloLens 2, a state-of-the-art device that enables the precise tracking required for near-fit placement of digital assets in real space, especially in relation to existing physical objects. To support the content creation, we also aimed to develop modular authoring software solutions (Rau et al. 2022) and codified design knowledge related to graphic effects, narrative structures and interaction patterns (Liu et al. 2021). For the development of the HoloLens 2 app on which the immersive experience runs, we used Unity with the Mixed Reality Toolkit (MRTK) plugins provided by Microsoft as a basis. On this platform, several exhibition-specific components were pre-configured as complex prefabs (referred to as "nuggets"), which could be used during authoring (Rau et al. 2022).

In the following, we summarise the aspects of the main demonstrator that we built to test the concepts with visitors on site at the Senckenberg Natural History Museum in Germany.

3.2 Application Design and Prototype

At the start of the AR application, visitors are first briefly instructed on how to use the head-mounted device and then familiarised with the virtual museum guide, which is a key feature of the demo application. An avatar, in our case an abstract blue butterfly, guides visitors from the entrance hall towards a chosen goal (see Fig. 1). During authoring, the avatar can be designed with different 3D shapes and animations, and either a fixed path to a specific destination can be given or, if the environment has been scanned beforehand, a variable guidance can be activated (Bitter et al. 2022). This feature can be particularly helpful for individuals who are visiting the museum for the first time or are not familiar with the layout of the exhibition. It is especially useful for longer routes, for destinations that require walking across several rooms. However, for finding destinations within sight, e.g. in the same room, placemarks are more useful as indicators, such as circles on the floor in our app. When visitors enter these circles, this can trigger certain content, such as the start of a narrative defined by authoring.

Figure 1: User following the flying avatar towards the whale exhibition

We have chosen the whale exhibition in the natural history museum as an illustrative example for the AR application. This exhibition offers the opportunity to show the diversity of marine mammals. Two skeletons of an orca and a fin whale are representatives of the suborders of toothed and baleen whales and can convey their differences to visitors. The species differ in their feeding mechanisms (hunting with echolocation vs. filtering using their baleen), and these distinctions are the focus of learning through the interactive AR application.

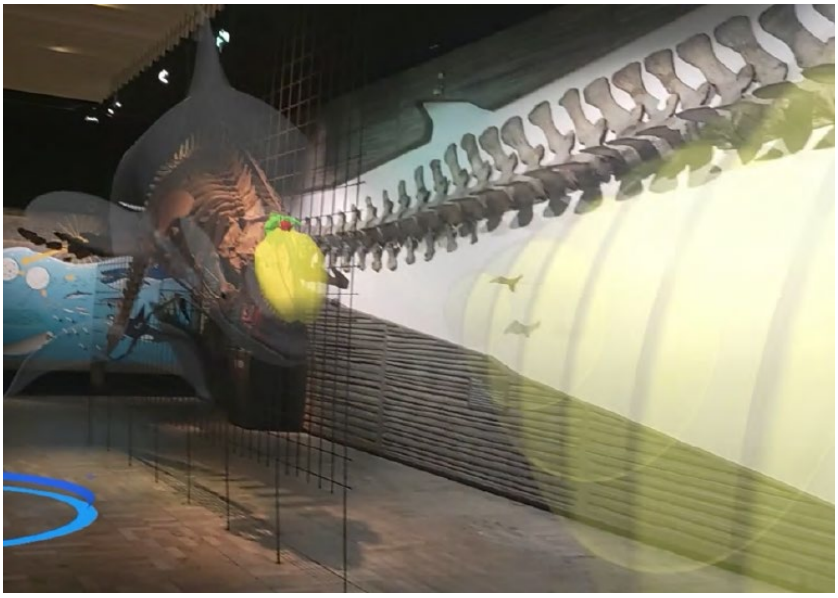

Figure 2: Visualisation of the orca's echolocation principle, viewed through the HoloLens

After arriving at the exhibit and triggering the narration, visitors hear a voice with general information about marine mammals and their characteristics, while the respective real bones or body parts discussed are

synchronously highlighted by virtual graphics. Users of the HoloLens app can then select specific information about the animals' various hunting techniques via menus. To convey this, three-dimensional animations are displayed in space within and around the physical skeletons. For example, the process of echolocation used by the orca when hunting can be visualised (Fig. 2). The details of this process are presented in steps that proceed at a pace chosen by the user, while the narrative voice explains each step in short sentences and 3D models of the internal organs involved are superimposed one after the other in the orca whale's skull. In Fig. 2, the yellow melon organ can be seen in particular, which at one point begins to focus the generated waves and direct them towards a target, during which an audible clicking sound can be heard. In the next step, in which a virtual prey fish is superimposed within reach, the waves are reflected back from it to the receiver in the skull. The abstracted sound waves in both directions are animated throughout and can be viewed by the user from any direction while walking around the exhibit and listening to the clicking, all in all an immersive experience for the visitor.

From the beginning, the AR application offers visitors the possibility to interact with the virtual layer. Since one of the main interaction styles of the HoloLens operating system is the use of a hand menu that appears next to the user's palm when they raise it into the field of view, we decided to use similar interaction options. Fig. 3 shows our customised hand menu next to the left hand, with buttons to be selected with the right index finger. It can be used to access different features or chapters of the application.

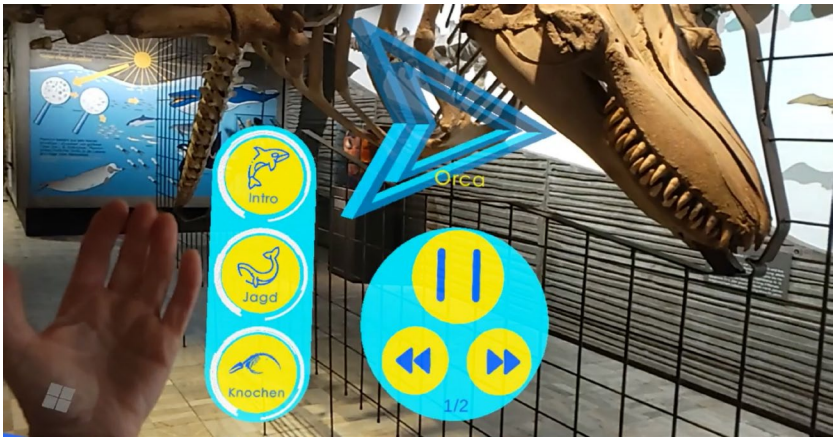

Figure 3: Hand menu of the HoloLens 2 application

In another chapter of the app, the user can control the display of labels on the bones that appear when approached from a certain distance. In this way, simple information about details of the skeletons can also be displayed. Additional text explanations for each bone group explain how the anatomy of both whales is analogous to that of a human.

Overall, the AR application offers an immersive and interactive learning experience. It responds directly to visitors' movements and choices. Therefore, our expectation was that it would increase users' engagement in exploring the real exhibition and motivate them to learn by visualising and comparing elements. We also hoped that the spatial experience of walking around among the 3D animations would provide a sense of immersion that would be enjoyable and intriguing, enriching the museum visit beyond learning facts.

3.3 Evaluation

A combination of quantitative and qualitative methods was used to evaluate our prototype. During individually supervised tours, user reactions were observed and recorded, and post-tour oral interviews and standardised questionnaires provided data on user opinions. For the observation of the viewing directions and user-selected content, the HoloLens viewport of the subjects was replicated on a portable monitor carried by a researcher who accompanied each participant on their tour through the museum (Liu et al. 2023). The evaluation itself was organised by a team of 8 people on 6 evaluation days on site at the museum. The test users were partly acquired in advance and could book a specific time slot, partly they were approached ad-hoc in the museum. For liability reasons, we have only addressed adults and excluded children under the age of 18. Participation was based on voluntariness and a certain level of pre-interest, which meant that self-selection bias could not be avoided. We expected that with regard to the HoloLens experience, mainly first-time users would participate.

Eventually, 109 test users could be recruited, of whom 48% were female, 50% were male, and 2% were undetermined. The results of the survey showed that respondents were overwhelmingly positive, but the

observation also revealed that there are still difficulties and disruptive factors that can pose challenges to museums and their visitors in making full use of the technology. In the following, we discuss those selected evaluation results that we consider important for a future use of this technology for game-based learning in museums, focusing on the general acceptance, the usability and the experiences of engagement.

Appreciation. Based on a 5-point Likert scale, we obtained 94% of the votes for the two highest scores (50% very good, 43% good), with no one giving the lowest rating. Further, 87% of participants confirmed that they would be willing to pay an additional fee for the experience if it were offered by the museum. Freely expressed opinions in the additional interviews mentioned the overall presentation of the information as positive, and 19 out of 109 respondents highlighted the particular added value of the experience for the museum. Many comments concerned the orientation function with the butterfly, which was rated very positively 48 times and mentioned positively 37 times but with suggestions for improvement.

Areas of improvements. The prototype also had some issues raised by users, which we do not classify as general problems but as opportunities for improvement for a revised version. Examples were some holograms that were too transparent, some labels that were not optimally positioned and should be clearer, or improving the quality of the voice output, which was a prototype electronic voice at the time of the evaluation. The most common criticism of the butterfly was that the speed was not satisfactory, mostly too slow, and the height of its flight. Although the butterfly already reacts to the users' speed and can for example wait for them, it should be even more adaptable. The feedback showed that all speed aspects, including voice, are very crucial for credibility and acceptance. Also, the narrative chapter control menus could be improved to give users better feedback on chapter progress and expected narrative duration.

Usability. Apart from selective need for improvement in usability, we were particularly concerned about how users were able to operate the app via the given hand menu (Fig. 3). The questionnaires showed that only one third of all users admitted difficulties with the hand menu. However, the observation logs show that a significantly higher number of users sometimes forgot how to access the menu during the experience or needed additional help to understand it properly. 37.5% of all subjects over the age of 50 experienced general difficulties with operation, while only 21.5% of those under the age of 50 had problems. Regardless of age, subjects with previous experience in augmented reality were less likely to have problems operating the app. Of 84 participants with no AR experience, 25% had problems, while this was only the case for 16% of participants with experience. These results are not surprising, but even though our entire subject group was self-selected, the results give us hope that there will be a target group for future immersive apps. However, opportunities for assistance in the museum would be essential.

Different preferences. In the interviews, different opinions were also expressed on some aspects, which gives us the impression that there are groups with different preferences. Some users mentioned that the app did not provide enough information, while others explicitly mentioned that the experience was inspiring especially in the parts where the animated visualisation could be explored without additional explanations. A few subjects expressed that the butterfly guide was superfluous, while a large group of users found it attractive. Some said that they would have liked more opportunities for active interaction, while others said that it was too much interaction for them and they would have preferred to just follow the narration. We think these are interesting aspects to explore in future evaluations, as we did not directly ask for such preferences.

Immersion and presence. Our questionnaire also did not directly address feelings of presence, however, through observation and remarks in interviews we received insights. Some interviewees mentioned that they had to reorient themselves after putting down the HMD, it felt like resurfacing from the sea they were in before. We found that when users followed the avatar, they seemed to focus more on this digital content animation rather than being able to connect it to the perception of the physical environment. On the other hand, our observations showed that users were often not intrinsically motivated to move around the exhibits and change their viewing position during the AR presentation, e.g. for echolocation, although this could have led to a stronger sense of spatial presence when perceiving the 3D holograms. Most users remained fixed in one place and did not move. We acknowledge that the situation of being observed may have had an influence on this, and we plan further research to explore how information load and presence are related.

3.4 Discussion

Based on our evaluation results and our experience in designing and building the prototype in collaboration between our university and the museum, we reflect on what our findings mean for the opportunities and limitations of using immersive (HMD-based) AR for game-based learning in museums of the future.

3.4.1 Chances

Our user evaluation supports the positive expectation that immersive AR with head-mounted displays will generate visitor interest in museums. New visitors could be attracted by the opportunity to participate in such an experience and, according to our findings, would be willing to pay an additional fee. Without being embedded in a game, the existing physical museum content enriched with interactive virtual assets created an interactive learning experience for visitors. Test users stated that the virtual overlay helped them gather information that would not have been as impressive without the AR layer. For example, the immersive explanation of echolocation as a 3D visualisation directly in the real physical skeleton gave them an impression they will not forget. The inclusion of animation can also greatly enhance the realistic impression of size and presence for visitors. For example, visitors were able to better appreciate the true size of the giant fin whale skeleton after the movement of a superimposed virtual model started in our app. Playful elements such as the butterfly guide were appreciated by most users, although some considered them non-mandatory and thus superfluous.

Even users who were using the HoloLens for the first time were able to operate the system after a short introduction, despite the possibly confusing unfamiliar way of interacting with the hand menu. If head-mounted displays also become established for consumer applications in the future, a larger user group will not have any problems in principle.

3.4.2 Limitations

However, some users already found an immersive HMD-based AR experience without gamification elements overwhelming. Learning new forms of interaction, experiencing something new for the first time, observing physical and virtual information simultaneously and paying attention to where people are stepping in the environment requires a high cognitive load. In recruiting our test users, we assumed self-selection and therefore may only have recruited people interested in technology, so we cannot yet directly assume that such an experience is transferable to a wider audience.

Technical difficulties in handling our app could be due to user error, but also to glitches due to immature technology or bugs, so that in our test intermediate help was required, which may interrupt the experience. In the future, it is expected that such an experience will require the constant presence of qualified staff. The special hardware may be a barrier to access for some visitors, as well as medical reasons that prevent the use of an HMD. However, no one reported simulator sickness in our evaluation.

Furthermore, the app currently isolates people, as groups cannot experience it together, only one individual at a time. A first step was to export the image of the head-mounted display to let others see what the main interactor is experiencing, but developing real multi-user experiences is part of future work. Also, the entire conception and implementation of the immersive augmented reality experience, including the design of interaction patterns and content options, was still part of applied research reserved for technology-savvy individuals, and we could not yet rely on established design principles.

4. Conclusion and Outlook to Gamification

We reported on selected evaluation results of our immersive HMD-based AR museum application and discussed the chances and limitations for the development of educational games that we inferred from the feedback. In order to proceed with our research in the framework of the EU-funded project "Locative Games for Cultural Heritage" (LoGaCulture 2023), we conclude with hypotheses based on these considerations. One work package aims to explore how engagement with cultural heritage can be enhanced by increasing the sense of immersion and presence through AR-based locative games in museums. To approach this, the different levels of experience addressed by these terms for games need to be explored (Marto and Gonçalves 2022). In a museum or heritage site, the sense of presence of the virtual content in parallel with the real physical environment is crucial.

Given the overwhelmingly positive evaluation by our test subjects, it seems reasonable to assume that applications like the one described above will flourish. Whether their further development will lead to games that can be implemented in museums depends, on the one hand, on how the identified limitations can be overcome. On the other hand, we need to set goals and priorities for the experiences we want to achieve and evaluate them after the development of the next prototype. Obviously, the costs of development and implementation are high for the museum in terms of organisation and staff, and the question is what prospects justify this effort.

We have identified the development of multi-user experiences that allow visitors to be co-present in shared AR scenes as an important sub-area of our future 'research by design' to address the fact that many visitors are not alone when they visit a museum. To tie in directly with our existing scenario, we design cooperative tasks, such as attaching labels together or answering quiz questions about the homology of whales and humans, 3D puzzles where visitors can put individual bones together, or interacting with echo waves about feeding whales virtual prey together. We will continue to develop scenarios and technical solutions in parallel.

In addition, we speculate that integrating competitive games into an immersive AR application could reduce the users' sense of presence with the physical exhibition or location they are visiting. In our example of the butterfly guide, we found that visitors may rush through an exhibition to reach a particular destination rather than taking the time to enjoy or explore the physical environment as well. Also whenever there were usability issues, such as difficulties with the hand menu, this distracted from the content and affected the flow of the experience.

Following the analysis of Paliokas and Sylaiou (2016) with their distinction between categories of 'game'-oriented applications and 'play'-oriented ones, we favour the play category. This would mean that players do not have to focus on strict game rules and objectives, but are offered small and playful interactions within the AR application that invite them to take their time and perceive the exhibits at their own pace. Users must be prompted to move and change their point of view in order to fully perceive the spatial presence of the virtual objects together with the real environment that the exhibit represents. Feedback from the system during cooperative play could encourage trial and error so that users explore the content. We think that further development of our application in this direction could lead to greater (co-)presence with the exhibits and other visitors. We plan to incorporate several such play ideas into our future prototype and test their impact on immersion, presence and ultimately learning and remembering to find out which level of gamification works best for immersive AR.

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Work, Costs and the Unexpected in the Academic's Creation and use of Games and Simulations in Teaching and Learning

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Abstract: Experiential teaching and learning activities such as games and simulations are increasingly popular in management education. The research has evolved specific clusters of concerns, principally; correlates of performance, the effectiveness in management courses, and what they can possibly teach. However, O'Flynn (2021) states that "the teaching viewpoint has been widely neglected." In management education research, costs, human or financial, of games or simulations, specifically towards the creator, the academic do not seem to be considered. Recent systematic reviews show the literature prioritising the effects of experiential learning, games or simulations and 'future research' guidance calling for more of the same. This leads to a simple research question "What are the actions, unexpected events, costs and risks in using experiential teaching and learning techniques, from the lived experience of academics?" This paper uses data from a British Academy of Management/Management Knowledge & Learning Division-funded project into the lived experience of management academics creating and using games and simulations. It presents an analysis of three cases that exemplify the categorisations created by this research to uncover costs, risks and emergent events that are generally unreported by the serious games and simulation literature.

Keywords: Simulation, Game, Management education, Lived experience, Academic

1. Introduction

Experiential teaching and learning activities such as games, simulations and practical activities are increasingly in-demand in management education. Chernikova et al. (2020) make the point that "real-life situations do not always provide enough practice opportunities…" Therefore, teaching and learning activities that can approximate to real-life in some way are desirable. This is where learning games and simulations come in. The role of simulation in management education is "…a simplified and contrived situation that contains enough verisimilitude or illusion of reality (or sufficient correspondence to the phenomena it purports to represent)" (Keys & Wolfe, 1990), so as to provide "interaction with a real or virtual object, device, or person and the opportunity to alter the flow of this interaction with the decisions and actions made by learners… to engage novices in practices that are more or less proximal to the practices of a profession." (Chernikova et al., 2020). Teaching that integrates 'doing' is valued by employers, academics and students alike (O'Flynn et al., 2021; Bradford, 2019; Wurdinger and Allison, 2017; Tomkins and Ulus, 2016). This situation has been lent a new imperative since the advent of ChatGPT and now the quest for teaching and assessment techniques cannot be corrupted by it. The cases of game creation and use here are all around strategy development and decision making. They develop discipline specific skills such as in the use of strategy tools, transferrable skills such a teamworking and also support the learning outcomes in terms of giving immediate opportunity to practice with the concepts communicated in the teaching programme.

The main research considerations in the literature in games and simulations in management higher education, according to Faria (2009), are; correlates of simulation performance, the effectiveness of business simulation/games in strategic management courses, and what business games teach (i.e. deFreitas, 2006; Kiili, 2007; Mayer, 2012). Recent systematic reviews e.g. Connolly et al. (2012), Chernikova et al. (2020), Manzano-Leon, et al. (2021), Subhash and Cudney (2018) and Zainuddina, Z et al (2020) tend to show the literature continuing prioritisation of the beneficial effects of experiential learning, games or simulations and 'future research' guidance calling for more of the same.

There is little on the lived experience of the academic that creates or uses these kinds of teaching and assessment technique and nothing on the costs and risks to them of doing this. Vlachopoulos and Makri (2017) metareview is rare in explicitly highlighting the importance of the "instructor's role as facilitator and motivator" in games and simulations. The creation and use of experiential learning techniques involves motivations, actions, unexpected events, personal costs and risks and is certainly not costless. Direction in the research for creating and using games and simulations seem to be normative statements on what academics should do in, rather than being based on recognition of what they do. The consequences of this under-research are that the academic is open to uncontrolled risk, which reduces the sustainability of games or simulations – in terms of avoiding wasteful-consumption of resources and in creating practices that can persist in use beyond the creator.

This leads to a simple research question "What are the actions, unexpected events, costs and risks in creating and using games and simulations, from the lived experience of academics?" This paper uses data from a British Academy of Management/Management Knowledge & Learning Division-funded project into the lived experience of academics creating and using games and simulations. It covers 13 cases of use of use of digital, in-person and mixed media games and simulations from classes of 350 to individual learners. This paper presents an analysis of three cases that exemplify the categorisations created by this research to uncover costs, risks and emergent events that are generally unreported by the serious games and simulation literature.

2. Brief Literature Review

Keys & Wolfe (1990) stated that, "second to the quality of the simulation itself, the administration of a game is probably the most important factor associated with a game's success." They also identified 'administration by the instructor' as a major gap in the literature around simulations. Fifteen years later, Arundell & Cioffi (2005) noted a research gap in practicalities of "preparing and implementing simulation in the classroom." More recently, there have been attempts in the literature to obtain the perspectives of academics using experiential education techniques. For example, Lund Dean and Wright (2017) with their experience of integrating experiential learning activities and methods in large classes. Tomkins and Ulus (2016) present a brutally honest account of their in-class performance. McCollom (1992) presents a first-person critical account of boundary setting in experiential education, dealing with challenges from colleagues and students. Jaaska and Aaltonen (2022) asked specifically "What are the benefits and challenges for teachers of applying GBL methods in project management education?" Hernández et al. (2010) identified roles of an instructor in simulations/games. Lameras, et al. (2016) gave very brief consideration of the teacher role in game activity. Wright et al. (2018) present a rare critique of the experiential learning concept regarding the ethics of academics in developing and using experiential education techniques. However, none of these look at how academics experience the creation and use of their games or simulations, the unexpected events, risks and costs.

Medical and legal education are important contributors to literature on the use of simulations. However, there too, there is little identification of the social, intellectual and physical resources required to develop a simulation. Through a systematic review, Zendejas et al., (2013) pointed out that even though researchers mentioned the term 'cost-effectiveness', there are no reported cost-effectiveness analyses. In legal education Ellmann and Kruse (2015) note that there are few specific comparisons of costs and benefits in experiential learning. Costs and risks in simulation literature are often conflated and obscured. Auman (2011) claimed to examine costs, but no actual costs are shown. In Mozier at al. (2006) it was found that main challenges arose from tangible resources - finance, physical and technological infrastructure, materials and academic support services; Intangible resources such as personal creativity and time; technical problems; student reactions; loss of control by the academic instructor over student learning. In reviews, risk is rarely named, instead talk might be of 'disadvantages' or 'unintended' events or outcomes. Any talk of cost or risk are mostly oriented towards the students, but some do consider those pertaining to the academic. Moizer et al. (2006) pointed out that simulations are more resource intensive during the development process, hence cost could be a barrier of developing simulations. Maloney and Haines (2016) show that the economic evaluation of the use of a finite resource should cover the question – "what is it that is being obtained, what do you need to give up to get it, and how does that compare to what you get with the next best alternative?" For those enthusiastic for experiential learning techniques, there could be a lack of enthusiasm for this question. Innovations and satisfaction could be threatened by a negative appraisal.

A project management life cycle can be a useful device for categorising the phases of the development of an artefact such as a game or simulation, such as Pinto and Slevin (1988) model of conceptualisation, planning, execution and termination stages. In education contexts, through their content analysis, Stewart, Denholm and Blackwell (2016) summarised the life cycle of developing simulations from three cases: initiation, development, in-use, on-completion. Cha and Maytorena-Sanchez (2019) pointed out that different efforts and competences are needed at each phase in a project life cycle due to different needs being targeted. Actions, unexpected events, costs and risks in creation and use of games or simulations can be set against these and such a categorisation also allows for comparison between cases of creation and use.

3. Methodology

In order to answer the research question, a purposive sampling of academics was made in order to maximise the available number of cases studies of the creation and use of a game or simulation. All participants, after agreeing to participate, were sent an introductory document featuring an explanation of the creation lifecycle

(see table 1) to help them order their memories. This lifecycle has been used in previous work by the author. There are alternative game design cycles, such as the iterative and complex GAMED methodology (Aslan and Balci, 2015), or Ramadan and Widyani (2013) and Roedavan, et al. (2021) GDLCs which are all based on the creation of a digital game. The lifecycle used here lifecycle is not limited to digital games, it also covers creation and use of in-person simulations and mixed-media simulations. The lifecycle is generally consistent with typical GDLC of pre-production, production, testing, and post-production. However, it goes into greater detail from the creator's point of view, from ideation through development to use in context, particularly integration into teaching and the wider organisation. It also focuses on the work of the academic throughout as they not only manage the game but also, teach. It is a tool for recall as much as it is a method for creation.

Table 1: The Work Lifecycle

Creation and Use Phase	Abbreviated description of Phase
Initiation Phase	The events or activities that put your mind onto innovating with a game or simulation This also includes preparing or negotiating with the institution for its use, consideration of learning outcomes, thoughts about integration with the wider teaching & learning programme and organisation.
Development Phase	The actual creation of the game or simulation, including activities to put it into use. choices about its degree of 'reality', activities, speed, tolerance and the integration or materialisation of the design into its physical aspects.
In-Use Phase	Students perform the work of the game, simulation or experiential activity and the lecturer works around it to ensure that it functions as intended. The intended learning outcomes may be obtained.
On-Completion Phase	All activities that have been designed to take place after the use of the game or simulation to ensure that learning is completed, obtaining student feedback, preparing for further use.

Data were gathered using a mix of guided email response and interview. As they recalled their experience in a systematic way, their mind was centred on three things of specific interest – 'normal tasks' in the work of creating or acquiring then using a teaching game or simulation, emergent or unplanned events in creation or use and then costs:

- Activities intrinsic to the nature of what you were doing, that were expected as part of the work
- Challenges that you were surprised by, that were unexpected and presented themselves in the course of the work. A 'challenge' is neither negative nor positive, it is simply an unexpected issue that presents itself in the course of performing the work, that requires response from you. It is a stimulus to action.
- A cost is what is given up or lost either in performing the expected and intended activities, or in making a response to a challenge.

Of the thirteen cases, three were selected for use in this paper. The cases were subjected to content analysis and categories emerged that were grounded in the data, rather than imposed from a theory or particular piece of literature. Ethical issues were around quality of recall, effects of disclosure and anonymising participants. The three cases selected for analysis are:

Case 1 – This was a case of an academic purchasing a simulation for use in an executive development programme. The simulation was to teach strategic management concepts, particularly the deployment of strategy through projects. He had no previous experience of using management simulations but knew that they were popular in business schools. He was connected to the CEO of a simulation creation company. He worked in a quite conservative culture so he knew to channel the resistance and questions his senior colleagues were likely to have, at the first meeting. He felt exposed to possible criticisms of the validity, credibility and legitimacy of his course. His case is marked by the social labour that had to be performed and the resistance from parts of his organisation, with one particular stakeholder actively diverting support resources from him. The actual work involved in running the simulation was lightened by the relationship that he had built with the CEO of the

simulation company and the collaborative attitude of the CEO in allowing him to shape it to the needs of his students. He was also aware of his personal brand and the brand of his institution and what leverage these gave him, also what success or failure would mean to those brands.

Case 2 - This was the case of an academic who had previous contact with management simulations whilst an employee of a leading aero engineering firm, on leadership development courses. After becoming a lecturer, he was asked to help facilitate a simulation on an MBA programme. However, he felt that the business simulations he had experienced were too simplistic and could easily be manipulated to 'win'. Therefore he decided to design his own. It was based on the design and engineering of a jet engine and the processes required to innovate and take it to market. It took time to design and there was no workload allocation for it, but he did not mind, because he enjoyed the work. The simulation was based on his own work experience and he was keen for students to not see it as a 'game' to be won, but an opportunity to address real life business challenges. There was considerable labour in supporting the simulation to move it along. Students needed to see the market reaction to their decisions, and the results of their competitors, before making the next set of decisions. A key part of the simulation was to be based on collaborating and competing against 3 other teams in the room, as in real life. He was surprised by how some students still found ways to manipulate the simulation and use the in-person relations between the teams in the room. It drove further innovation. He was clear on wanting to create something unique to him for his 'personal brand'.

Case 3 - This was the case of an academic who created a simulation based on an idea suggested to him by a student, following an intensive three-day programme built around a case study – why could the case study not be turned into a playable game? It was based on the historical case of Honda entering the USA for bike sales in the late 1950s, meeting with emergent events that transformed their strategy from the sale of large bikes to small ones, which finally established the brand in the USA. With this moment of inspiration, the game logic was quickly established along the lines of the story in the case. Additional research was needed to create all of the required variables, such as historically correct options and prices and how these could be assembled into an Excel sheet and made playable. The win condition was easy to determine – stay alive and win in the face of emergent events, as in the case study. A powerpoint was created to run alongside it to carry the narrative. However, in early tests, the simulation was too harsh and almost impossible to win, even for the creator. So, it had to be relaxed. There was no particular resistance to the innovation as the teaching module was entirely his. At first use, he was surprised and slightly embarrassed at the loopholes that students discovered, going back in time using the spreadsheet and running parallel universes to test out different choices. Students responded well to the simulation, but time taken in correcting flaws and in supporting the students to assimilate the instructions and routines of play meant that the debrief was compressed.

From the three cases, categories of activity, unexpected issues and costs across the game/simulation development and use lifecycle can be extracted as below.

4. Findings

Initiation phase

Normal events here included moments of inspiration from intentionally thinking back over the personal past or concerns with existing simulations or teaching activities. Existing solutions may be considered. There are immediate concerns with social relations within the academics context – seeking relationships and managing stakeholders, even before any development work is done. Game/Simulation mechanics are considered in parallel with pedagogic concerns. Unexpected issues emerge from seeking those organisational relationships, unexpected help or resistance emerges early. Tension between what is desired and what is actually possible manifests early and the work to integrate pedagogic concerns with game mechanics can reveal unexpected new information. Costs include Non-labour direct development costs, cost of materials, the paid cost of labour and unpaid voluntary work (hidden labour).

Development phase

The social work of seeking relationships and managing organisational stakeholders continues. Now the unpaid work on the simulation/game has to be balanced with existing work commitments. The tension between Game/Simulation mechanics and parallel pedagogic concerns continues, drawing in research, the developers personal past and new relationships. Within this tension are concerns over verisimilitude, delivery mechanisms or channels, integration with the wider teaching programme, integration with assessments. Outputs are now born from the materialisation of the ideas, viable products and support documentation, which are subject to testing or piloting. Deadlines and time constraints are manifest. Unexpected issues emerge from all of these

normal activities that continue to shape the game/simulation. Inspiration moments also emerge from this tension. Costs continue as before but as the ideas are now materialised, there are materials costs, with the additions of costs from negative relationships with others, meetings, investments and acquisition of specific resources such as licences.

In-use

The movement of the created object from the safe confines of the academic to the reality of the classroom involves labour. There is physical and mental/emotional labour. Interactions with students include facilitation, informational exchange, monitoring of their behaviour. Interactions with fellow academics or facilitators may occur in training and then running the game/simulation. Work is done to maintain integration with the wider teaching programme and to ensure any element required for summative assessment is delivered. There are tensions with time, which may run faster or slower than expected. Social labour with the organisation and stakeholders continues. Unexpected events arise from the normal work, specifically student behaviour being inconsistent with the instructions or operation of the simulation/game, also inconsistent behaviours from facilitators. More training might be required. Some unexpected developments might arise that are not necessarily problems – students can have useful insights, some features of the simulation might be more powerful than intended. Negatively, limitations of the simulation can be revealed in use, or errors are identified by students, emergency work by the academic or fellow facilitators is required to maintain the operation. Costs continue as before with the additions of physical/emotional/mental cost to the academic, labour also rises as problems require fixing outside of classroom hours. Time pressures can exacerbate all of these.

On-Completion

The completion of the simulation/game involves much the same labour as in-use. However, there are some distinctive works around debriefing. Feedback comes from students or organisational stakeholders through planned formal channels. Work is done to ensure integration with the teaching programme and the summative assessment. Unexpected events arise from how the simulation ends and the debrief. Feedback from students and organisational stakeholders can come from outside of the formal process. This can generate unexpected work in the debrief, but also it can be positive, leading to ideas for development. Successful completion can create opportunities to expand the game/simulation to other parts of the organisation. Completion that is less than successful can lead to impact on physical/emotional/mental state of the academic. Completion also marks the end of student activity, causing possible disengagement through relief, fatigue or excitement, before the debrief. Even in normal working, the fatigue created can impact on the debrief. The debrief can also be crashed by time constraints, especially if the simulation required unexpected works during use. The debrief can also be affected by the same unexpected events during in-use, especially students and facilitators not behaving according to the instructions. The costs remain the same as in-use.

5. Discussion

The Stewart, Denholm and Blackwell (2016) lifecycle of simulation development was sufficient to help respondents systematically recall their experiences and as a basis for categorisation of those.. The effects of social relationships are present throughout the lifecycle. However, O'Flynn (2021)'s comment that creation of experiential activities is done by lecturers creating together was not borne out by the cases. The participants appeared to act alone from the moment of inspiration, initially in an artisanal mode, with academics drawing from their personal histories and concerned about their 'personal brand'. Concerns with existing provisions are noted and those who are part of the existing provision might also be resistant. Consistent with Wright et al. (2018), there was no talk about ethics. Physical actions needed for both normal operations and emergencies in the mechanisms of the activity, resources or organisational context, lead to fatigue and inconsistent performance from the academic or facilitators. This is consistent with Tomkins and Ulus (2016) calling such innovating "a gamble one makes with one's body and one's self". Moizer et al. (2009) pointed out that simulations are more resource intensive during the development process, but in the data here it appeared to be at in-use phase.

In terms of costs, actual cash sums were hard to obtain. It was the first time that participants had been asked to consider this, which would suggest that the lack of cost and benefits analysis in the literature reflects reality. Costs that were obtained bore little relation to each other. It seems that the challenges noted in the literature review from medicine in Maloney and Haines (2016) hold true here, that diversity of techniques and variations in stakeholders, make generalisation difficult. The amount of unpaid labour was notable as was the human cost of dealing with negative relationships as the creator encounters resistance, inconsistent behaviour and the

limitations of their designs. Creations may start at an individual level, but to become part of an organisation requires interaction with others, eventually in meetings. The cost of meetings in the development of experiential techniques is not considered in the literature.

All other normal events and most of the unexpected events are consistent with Moizer et al. (2009), 'challenges', however there are some that are new to the literature. For example, the social work that must be done to build a lasting practice, to overcome resistance and the ways in which organisations can push back against the innovator. The limitations of testing - the test is still a work of the creator and under their control, with tacit compensatory work-arounds , but in use, the technique is truly exposed and used by people without an automatic love of it or the workarounds. Through the unexpected events, a categorisation of risks also becomes apparent, though not all unexpected events are risks, some are opportunities. Students finding errors or responding to elements in an unexpected way may indicate where improvements to instructions or operations could be made. Negatively, this can develop a bad attitude towards the activity and stress for the academic and evidence for those who would resist the innovation. Especially this is so where facilitators might give students clashing information, causing uncertainty. This forces the academic to act to correct under time pressure. The problem with planning for the risks identified here is that their true nature may not be revealed until the activity has achieved such scale in development or use that it arouses reactions to both the creation and the creator. Until that point, the game/simulation is someone else's problem.

6. Conclusions

This paper has presented a sample of findings related to our research question "What are the actions, unexpected events, costs and risks in using experiential teaching and learning techniques from the lived experience of academics?" The findings from the three cases show that intended actions of creation move the academic along in a process of creation where tensions between pedagogic concerns and game/simulation logic change into tensions between intentions and material reality. These are revealed in-use and unmanaged risks can manifest as unexpected events and generate costs. These costs can be generally categorised, but finding precise financial data was not possible. It is the intention of this research to reduce the 'unknown unknowns' that an academic developing a teaching game or simulation might discover. It also centres the academic's lived experience in creating and using games and simulations in teaching and learning, which is rare in the literature.

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Evaluating Playful Creative Problem Solving in Kyiv and Ukrainian Refugees in France

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Abstract: Creativity in playful creative problem-solving (CPS) is influenced by the emotional state of the learner-player. In this study, we evaluated how stressful situations (such as conditions of war) can impact divergent thinking (DT) in CPS. To evaluate divergent thinking, the main components of which are fluency, flexibility, and originality, creativity researchers have developed the Alternative Uses Test (AUT), where participants are asked to write about different uses of familiar objects in a limited amount of time. In educational robotics, DT has been operationalized with the same components of fluency, flexibility, and originality based on the diverse configurations made by the learner-players. In the present research, we engaged participants in a playful activity with modular robotics to evaluate divergent thinking. Participants engaged in the CreaCube task are Ukrainians. We recruited two groups of participants: Ukrainian refugees living in France and participants staying in Kyiv (Ukraine). These participants are experiencing a stressful situation due to the daily war events in Kyiv during the development of this study (missile attacks, power and heating restrictions, air sirens, and limited communication with partners on the frontlines). By comparing these two groups of learner-players in the CreaCube task, we aim to identify how stressful situations affect divergent thinking. The preliminary results showed that flexibility and originality as DT components of the participants from Kyiv in the first experiment are significantly higher than those of the refugee participants based in France. This may indicate that the participants from Kyiv, having been in stressful situations (war conditions) for almost a year, have developed more original ideas (originality component) and different ideas (flexibility component), which could be explained by the daily problem-solving activity under war constraints. Playful situations under war conditions permitted the Kyiv participants to distract themselves from the current situation and show originality in thinking better than participants playing in France who were not in stressful situations. This may indicate that wartime constraints have engaged the participants in better strategies for generating novel ideas, but it also indicates that the interest in game activities has a positive effect on DT even in stressful situations for the participants.

Keywords: Divergent thinking, Creativity, Fluency, Flexibility, Originality, Wartime

1. Playful Educational Robotics

1.1 Educational Robotics in the Classroom

The current stage of the development of science and technology is characterised by the growing popularity of robotics and the expansion of the scope of robots (Akcaoglu *et al.*, 2017; Buchem and Bäcker, 2022; Chevalier *et al.*, 2022). Teaching youth to design, program, and use robots and robotic systems relates to the requirements of today, namely the emergence of new professions in the field of robotics and, as a result, the need for relevant specialists. In the present world, increased attention is paid to robotics as an applied science, including its educational and developmental potential. *Educational robotics* is a cross-disciplinary area of students' learning. Its process integrates the knowledge of STEM subjects (physics, technology, mathematics), cybernetics, mechatronics, informatics, and digital technology. Teaching educational robotics corresponds to the idea of advanced training (learning the technologies that will be needed in the future) and allows students of all ages to be involved in the process of innovation, scientific and technical creativity (Morze, Strutynska and Umryk, 2018a).

Educational robotics classes ensure the implementation of interdisciplinary links with STEAM subjects, as well as the practical application of theoretical knowledge. According to Morze, Strutynska and Umryk (2018b), such classes include the following components:

1. The idea of creating a specific robot and the corresponding technical task.
2. Modelling of the robot.
3. Design of the robot.
4. Build a robot algorithm and program the robot in accordance with the technical task.
5. Testing the robot.

One of the most effective ways to do this is to propose learning research projects for students, such as:

- *Plant Pollination project* (creating a robot for plant pollination - modelling the relationship between a pollinating insect and a flower at the stage of reproduction) - integration of biology, robotics, and programming.
- *Flood Protection project* (designing an automatic gateway to control water levels in accordance with different rainfall patterns) - integration of technology, robotics, and programming.
- *Ocean Cleanup Project* (designing a prototype robot to remove plastic debris from the ocean) - integration of ecology, technology, robotics, and programming.
- *Project "Space Exploration"* (design of a prototype robot all-terrain vehicle for exploration of distant planets) - integration of technologies, robotics, and programming.

The implementation of such projects contributes to the development of the key competencies for the 21st century, such as the #5c21 framework, which includes collaboration, problem solving, critical and creative thinking, but also computational thinking, and research skills (Morze, Strutynska and Umryk, 2018b).

Incorporating basic knowledge of the fundamentals of robotics into school education will enable the training of specialists for future jobs related to industries that do not exist today. It is important to remember that the use of educational robotics makes it possible at an early stage to identify the technical inclinations of students and develop their technical creativity (Morze, Strutynska and Umryk, 2018a).

1.2 Playful Activities Engaging Children in Creative Problem Solving in Educational Robotics

The positive impact of the game approach on the development of critical thinking, collective creativity, and problem-solving skills was considered by Tang, Vezzani, and Eriksson (2020). Learning to be imaginative and creative requires open and flexible environments rich in materials and role models that reflect the cultural life of their communities, e.g., songs, crafts, languages, and artefacts. Language mediation within semantic tasks, as in the *Alternative Uses Test* (Guilford, 1967; Beaty *et al.*, 2022) but also musical instruments in the case of musical creativity and STEM artefacts (robots, electronic components, etc.) in the context of creative problem solving (CPS) with technologies (Charisi, Liem and Gómez, 2018). CPS can be supported with visuospatial constructive play objects (VCPO) or artefacts such as modular robotics (Ness and Farenga, 2016). In the CPS tasks with modular robotics, creativity can be observed not only by the analysis of the configurations but also by the behavioral learning analytics, including the gestures and actions of the participant engaged with the mediating artefacts.

2. Creativity: From Divergent Thinking to Convergent Thinking

Creativity is a complex human process that can be observed in a high diversity of learning, professional, and personal tasks. Despite being considered a transversal competency by most of the 21st century skills frameworks (Burkhardt *et al.*, 2003; Care, Griffin and McGaw, 2012; P21, 2019), creativity needs to be considered in the specific context of an academic domain and task. Moreover, the results on the assessment of creativity show how the same subjects can have different divergent thinking (DT) scores depending on the task and the materiality of the artefacts engaged in the task (Leroy, Romero and Cassone, 2021; Romero and Barma, 2022). Guilford (1967) underlined the potential benefits of creativity, which could have a positive influence on society in light of issues like maintaining peace, providing for a rising global population, and improving the educational level in general (Guilford, 1967; Lubart, 2017). The 7 C's framework for conceptualising work on creativity proposed by Lubart (2017) shows that creativity can cover many different aspects and be expressed in different forms of activity, from the creation and context of ideas and productions to their consumption.

In this study, we focus on CPS tasks in which the learner is engaged both in DT (ideation) and convergent thinking (idea selection) processes in different cycles of iterative improvement. DT is the process of creating multiple, unique ideas or solutions to a problem that an individual is trying to solve. Through spontaneous, free-flowing thinking, DT requires coming up with many different answers or routes forward, which is an important aspect of CPS (Runco, 2011, 2014). In CPS, DT corresponds to idea creation, while convergent thinking corresponds to idea selection.

DT is a cognitive process that leads to the creation of various ideas and their advancement in different directions in a problem-solving situation. Some of these ideas are conventional, and some are original. The three main components of DT are *fluency*, *flexibility*, and *originality*, as defined by Guilford (1967). DT components permit us to differentiate between the *fluency* of ideas, even if they are not original, the *flexibility* of ideas showing a certain difference with prior ideas, and *originality*, which are the ideas appearing to be rare within a certain

group of references. DT allows an individual to identify the fullest range of alternatives and possibilities. DT is not linear and does not lead in only one direction but instead branches out so the individual has more freedom, latitude, and a very full set of options (Runco, 2022).

DT has been thoroughly studied and is considered an important process in creativity research. Originality, as one of the DT components, is an extremely important characteristic because it is a prerequisite for creativity (Acar *et al.*, 2019). DT tests are very often used in creativity studies and as measures of creative potential (Runco and Acar, 2012; Runco *et al.*, 2016). By no means is DT synonymous with creativity, but results from DT tests have proven to be informative about the potential for CPS. DT tests offer information about originality, one part of the standard definition of creativity, as well as flexibility and fluency with ideas (Runco, 2022).

To test DT generally, the Alternative Uses Test (AUT) is used, which asks participants to describe or write several uses for known items to tell lots of different ways how the spoon, wheel, toothbrush, etc. can be used (Wallach and Kogan, 1965), or other ideation tasks that are not only semantic but also can engage the learners' in drawing or other DT activities (Torrance, 1972; Abdulla Alabbasi *et al.*, 2021; Acar *et al.*, 2021; Runco, 2022).

In the present study, we focus on the creators' DT and the actual creation (configuration) made with a set of modular robotic cubes. In our study, we aimed to evaluate the three DT components (fluency, flexibility, and originality) through an educational modular robotics task that engaged the Ukrainian participants in building their ideas during stressful situations (war conditions).

3. How Stress can Impact Creativity

It is believed that creativity requires a positive emotional setting to be supported. For instance, Stinkeste, Napala, and Romero (2021) show that, both in individual and collective settings, a positive climate is very important to support CPS. In STEAM activities, team climate has been observed to support the creative process in relation to co-creativity. Other researchers studying the impact of stress on creativity indicate that their relationship is controversial and much disputed because stress can affect creativity either positively or negatively.

Anderson, De Dreu, and Nijstad (2004) claim that stress may boost creative thinking in organizations. According to their findings, stress is a source of extrinsic motivation and raises arousal levels. As a result, when people are under stress, they may utilize a concentrated problem-solving method that promotes creativity. Other studies show that stress can reduce creativity. Thus, according to the meta-analysis in psychology studies developed by Byron, stress tends to reduce creativity by putting a strain on cognitive abilities, leading to the employment of straightforward cognitive techniques that are likely to decrease originality (Byron, Khazanchi, and Nazarian, 2010).

The study by Kassymova *et al.* (2019) investigated the extent to which stress affects students' academic success and health. Investigating the following dependencies, they also found that stress and creativity interact in an ambiguous way. On the one hand, stress suppresses creativity, like all other intellectual abilities. On the other hand, stress encourages people to search for new forms of response, i.e., to be creative. The nature of creativity in a stressful situation is largely related to the *type of stress*. The more stressful a person is, the higher and more extensive their creative achievements are. On the third hand, a person's creative abilities help him or her to easily endure stress, sometimes without noticing it. Fourthly, a person's creative abilities can lead them to specific stressful situations related to the need for their realisation (Kassymova *et al.*, 2019). Thus, a person's creative abilities can be an important source of stress resistance. Based on these different studies, we need to consider the relationship between the domain and the tasks in which creativity is studied in relation to stress.

3.1 Play under Conditions of war

Safety is an important human need for all citizens. During wartime, children and adults suffer from different types of chronic stress, which can have a long-term impact. The literature review of Elbedour, ten Bensel, and Bastien (1993) has identified the wartime effects on the child's psychological development, especially if their adults' figures of reference have not developed coping strategies. The child's adjustment is also affected by their community stability and social services, which require them to consider the importance of the school's educational activities in supporting the well-being of the children. Moreover, when free play outdoors is diminished, this can also be an aggravating factor for mental distress (Gray, Lancy and Bjorklund, 2023). As educators and researchers, we do not have the possibility to stop the war, but we can imagine different ways to support Ukrainian educators, researchers, and, most importantly, Ukrainian children through playful activities.

When the war in Ukraine started, we wanted to know how we could help Ukrainian colleagues in the learning sciences and support their educational efforts during wartime. The research and societal values of the MSc *SmartEdTech* of Université Côte d'Azur are to develop learning activities that can support the sustainable development goals (SGDs) with a special focus on quality education (SGD4) "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"? We organised our first activity in 2021, inviting female researchers in STEM education from Ukraine for a special webinar on Women's Day of 2021. Afterwards, we had the opportunity to support Prof. Oksana Strutynska, full professor at Kyiv, in joining the *Let's STEAM!* and *ANR CreaMaker* projects in the LINE research lab. We then organised two workshops in Nice including supporting unplugged computer sciences activities developed within the Unplugged Quest project in 2022. In January 2023, Prof. Strutynska flew back to Kyiv for Christmas and after the holidays, she also ran different individual and collective playful sessions at the Faculty of Mathematics, Informatics, and Physics at the Dragomanov Ukrainian State University.

4. Methodology

4.1 Participants

The experiment involved 33 Ukrainian participants, who were divided into two groups: Ukrainian refugees in France and participants from Kyiv (who were in stressful situations - conditions of war). The participants were presented with a playful activity with modular robotics to evaluate divergent thinking, the CreaCube task.

In the workshops developed in Nice in 2022, we engaged Ukrainian families among the refugee community in Nice. Most of the children are well-integrated in primary and middle schools but have different levels of French proficiency, which made the translation of some terms necessary, and different levels of prior knowledge in computer sciences. The participants were invited to the LINE lab in Nice, and after the activities, we shared some snacks to support team building and the opportunity to debrief not only about the Unplugged Quest activities but also in relation to their daily challenges. We involved 17 participants in a playful activity in Nice.

We organised the workshops in Nice on a non-school day to allow the parents to come with their children. We shared with the parents the Unplugged Quest activities. They appreciated the diversity of languages in the activities that support their children's language learning. On the Nice team, we are amazed at the courage of the volunteers who were joining these activities.

In Kyiv, Prof. Strutynska proposed the participants join the Faculty of Mathematics, Informatics, and Physics at the Dragomanov Ukrainian State University (Ukraine), according to the safety measures during wartime. Participants reported enjoying the playful activities. We involved 16 participants in the experiment. During the workshop, we took all the necessary measures to ensure the safety of the participants. During air raid sirens, we went down to the shelter. After the danger was over, we returned to the game activities.

4.2 Evaluation of Divergent Thinking

To evaluate divergent thinking, learner-players are asked to solve the CPS CreaCube playful task. The resolution of the CreaCube activity involves the manipulation and assembly of cubes. In order to complete the game's objective, the player must investigate unknown cubes and make an autonomous vehicle that can move from the starting point to the final destination (Romero, DeBlois and Pavel, 2018). In this way, we can analyze the process of CPS to evaluate the DT components for every participant.

Participants are required to build an autonomous vehicle that can move from the starting point to the destination using Cubelets modular robotics. Participants build different options for vehicles (*fluency component*), including different ideas (*flexibility component*) and original ideas (*originality component*). Based on the operationalization of the AUT by Guilford (1967), we evaluate DT in the CreaCube task using the three DT components. *Fluency* corresponds to the total number of distinct ideas; *flexibility* corresponds to the number of distinct categories; and *originality* is the rarest response, corresponding to those provided by fewer than 5% of all participants within the same age category. Participants are invited to play again after their first success in the CreaCube game. The goal of the second attempt is to determine whether the player has learned and considered the cubes' characteristics from the first attempt, as well as whether they have tried to solve the problem by creating a new solution or trying to duplicate the first solution exactly. These next actions also prove to evaluate the DT of participants.

5. Results

During the experiments, all learner-players had two attempts at the CreaCube activity (A1 and A2). In each attempt, we obtained results for three DT components: fluency, flexibility, and originality. After experiments, we analyzed the participants' activity from videos by using specially developed software in which the figure configurations are pre-set (Figure 1).

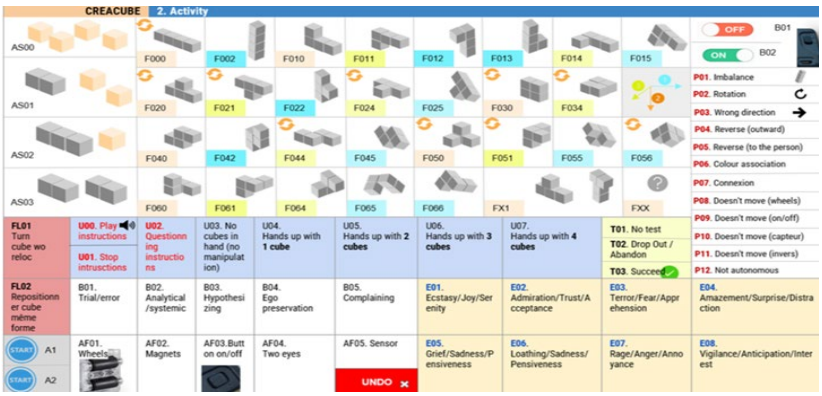

Figure 1: Ad hoc developed software for analysis DT components

Once the video is uploaded to the CreaMaker research platform, it is analysed by integrating the corresponding coding schemas (Figure 2).

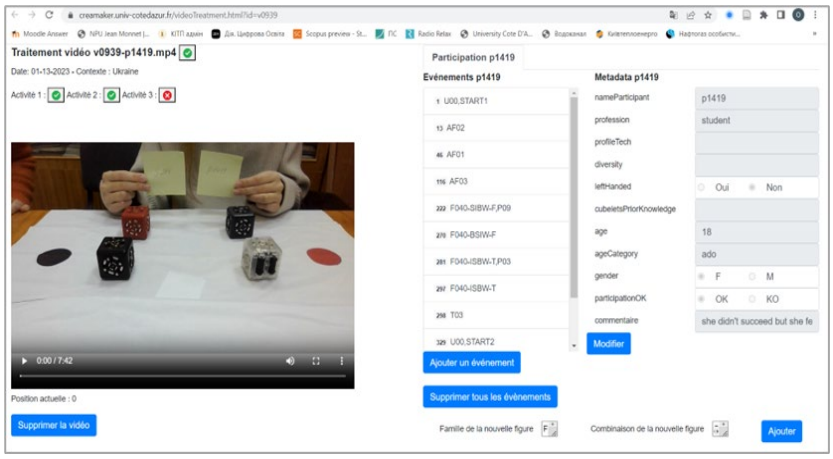

Figure 2: Video analysis using the figures coding schema to calculate the DT scores

We processed the videos using this specially developed software, based on which the DT components are analysed based on the video analysis through the CreaMaker platform. The results analysed with JASP (0.17.1 release) are shown in Table 1.

Table 1: DT components' scores for Kyiv and Nice participants

	A1_Fluidity		A1_Flexibility		A1_Originality		A1_Time		A2_Fluidity		A2_Flexibility		A2_Originality		A2_Time	
	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice	Kyiv	Nice
Valid	16	15	16	15	16	15	16	15	14	15	14	15	14	15	14	15
Missing	0	0	0	0	0	0	0	0	2	0	2	0	2	0	2	0
Mean	4.938	4.933	2.188	1.600	1.188	0.133	206.063	223.800	2.857	2.600	1.214	1.200	0.286	0.333	71.000	87.800
Std. Deviation	5.234	8.996	1.974	0.632	1.471	0.352	148.486	227.507	2.381	3.757	0.802	1.265	0.611	0.816	36.574	93.253
Minimum	0.000	1.000	0.000	1.000	0.000	0.000	68.000	64.000	0.000	0.000	0.000	0.000	0.000	0.000	21.000	19.000
Maximum	19.000	37.000	7.000	3.000	5.000	1.000	539.000	655.000	9.000	15.000	3.000	5.000	2.000	3.000	140.000	307.000

We can observe in Table 1 a higher level of flexibility (m=2.18; sd=1.97) and originality (m=1.19; sd=1.47) in the first instance (A1) of the CreaCube task among the participants in Kyiv than those in Nice.

The next figures focus on the DT components with the highest differences between the Nice and Kyiv participants. Firstly, figure 3 shows the difference in the first instance of the CreaCube activity (A1) on the originality DT component. We can observe that Kyiv participants are more original (m=1.18; sd=1.47) than those in Nice (m=0.13; sd=0.35). The Welch's t-test ($t(16.821) = 2.784$, $p = 0.013$) suggest that there is a significant disparity in originality scores between the Kyiv and Nice groups.

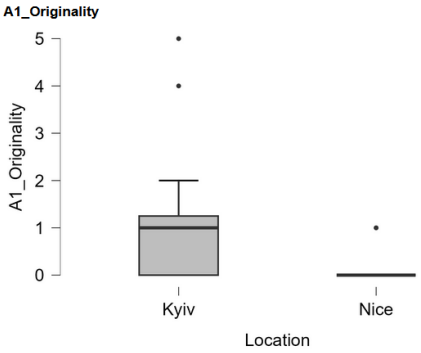

Figure 3: Originality in A1 among Kyiv and Nice participants

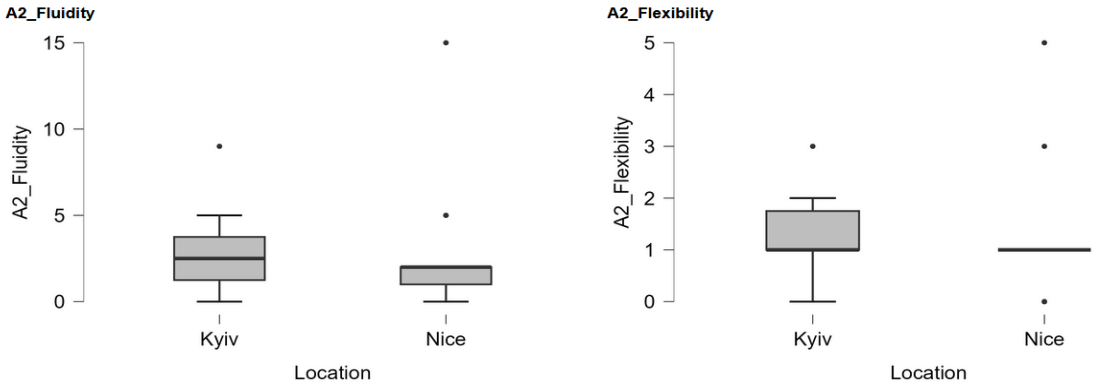

Figure 4: Fluency and Flexibility in A2 among Kyiv and Nice participants

We can observe that despite a similar average, the distribution of the DT scores of fluency and flexibility in A2 are more diverse among Kyiv participants than those in Nice. There was no significant difference in fluidity scores between the Kyiv and Nice groups in A2, $t(27) = 0.218$, $p = 0.829$, neither in flexibility, $t(27) = 0.036$, $p = 0.972$.

6. Discussion

The analysis of the Nice and Kyiv participants shows some differences, especially in relation to originality in A1. The second activity (A2) shows a lower level on each of the DT components, which is a normal observation due to the prior experience acquired when solving the first instance of the task.

The higher rate average value of the originality component (A1, see Figure 3) of the Kyiv group compared to the Nice group can be explained by the fact that learner-players from the Kyiv group daily face the need to solve various problems due to the wartime stress: lack of electricity, heat, and sometimes water; difficulty in cooking in the absence of electricity; closed shops; household appliances do not work; ATMs do not work; need to interrupt studies, work, and moving around the city during air raids; constant stress due to the war, etc.

Therefore, their readiness to solve problems in the novelty situation of A1 is higher among the Kyiv participants than that of the participants from the Nice group. In addition, in such difficult war conditions, the opportunity to attend a playful activity with modular robotics CreaCube also brought participants from the Kyiv group positive emotions and distracted them from the current situation in the country. This allowed them to relax, which can also serve as an additional factor in a higher level of CPS.

Despite a limited sample size, this study is an opportunity to consider playful interventions to help Ukrainians engage in creative activities and value the DT capacities developed under the stressful situation of war. Both the experimenters and participants in France and Ukraine reported a highly positive playful experience that, beyond the DT indicators, is a positive intervention to support Ukrainians through game-based learning activities.

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Sense-Making of Digital Game Technologies (DGT): Positive Instances of Children-Led Engagement With Chess

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Abstract: The Game of Chess, a drosophila of reasoning, is a unique opportunity for nurturing children into systemic thinking approaches that naturally embrace the higher-order thinking skills required for STEM aspiration. In this paper, we conceptualise chess from a digital game technology perspective to nurture a rich system thinking experience and illustrate the various attempts to introduce a digitally immersive classroom experience for children using a generation of digital chess infrastructure. We continue to illustrate a few positive hands-on experiences of deploying generations of digital chess infrastructure for group learning in the classroom environment for nurturing both the learning and the social imagination of children working together to expand their quest for chess. We examined what brought the attention, advocacy, and achievement to build an agency for chess. With no prior value claim existing for the advocacy of technology deployment with chess in classrooms, the present framework shows how the attention to chess is progressively enriched. Further, the positive instances of children-led engagements demonstrate the goal of steadily integrating digitally immersive chess experiences into classroom learning environments. We make sense of the social imagination of classrooms and make in-vivo observation on children-led empowerment, shared aspiration, competency building and the evolution of contemporary practices in chess leading to the agency for chess. We conclude that a transformative opportunity exists through deploying a digitally immersive chess environment within the classroom for nurturing systemic thinking in children with chess.

Keywords: Chess, Chess in school, System thinking, Digital game technologies, Social imagination, Bridging.

1. Introduction

Chess has always been a sensation and universal appeal to mass media, whether it comes to Chess games relayed from Trans-Atlantic cables matches in 1861, chess played during the Space-mission in 1970 or Najdorf's blind-folded simultaneous in Argentina 1944 reaching the news media in Europe in the heart of World War II. During the Information Age, inventors and pioneers of technology turned to their chess wisdom to appreciate the knowledge representation and gain deeper insights into scientific, mathematical, economics, engineering, and technology fields. . The very nature of the digital representation of Chess embedded within a perfect zero-sum game and the applied nature of formulation of massively sprawling game trees and evaluations encapsulate scientific, technology, engineering, and mathematics (STEM) principles. The achievement of general-purpose computing expanding the trade-off in memory vs. search and its enabling technologies have continued to thrive with artificial intelligence (AI), Cognitive Architectures, and Information Communication Technologies that have all become the foundations of today's technology-integrated society.

Further, with extraordinary achievements coming with children from early teens, and international federation efforts to popularise chess for children, as a global movement for securing the future of chess, there has fundamental shift to relating Chess and its social opportunity to classroom pedagogies. The Game of Chess, a drosophila of reasoning, is a unique opportunity for nurturing children into systemic thinking approaches that naturally embrace the higher-order thinking skills required for STEM aspiration. However, Vuk (2022) recognise the clear exclusion of chess in both pre-collegiate and higher education and continues to highlight missing romantic links between Chess and Natural science in the context of developing lessons in creativity for students to unleash various analogies that consistently illustrate sporadically with positions from real-life chess games. Simon and Chase (1997) brought the interest in nurturing cognitive architectures and chess engines with powerful AI-based search engine technologies to explore bounded rationality and expand the limits of human cognition. However, in reality, a core perspective that is least considered in chess is the deeper understanding of the goal-based approach to chess that nurtures systemic thinking. Kasparov (2010) in his epic best-seller How Life Imitates Chess limits the contextual dynamics of the Material-Time and Quality factors to drive the systemic dynamics within the game of chess. However, the Last three decades have spawned with Computer-assisted Game Preparation, after the class of AI technologies has long surpassed human gaming abilities in chess. Further, it is important to consider the sophistication of the combination of such *digital attributes* with *seamless technologies* that combine within the realms of gaming to bring a true and immersive learning experience that is collectively appreciated in the context of chess within classroom settings.

Fisher DM and the Systems Thinking Association (2023) claim that the sequence of system thinking concepts and capacity building are appropriate to the very start of education processes and throughout K-12 education. The ability to understand systems, predict their behaviours, and devise modifications to them to produce desired effects are all within the realm of gaming experience with chess that can now grow as a part of classroom processes. Fisher and the Systems Thinking Association (2023) further recognise systemic thinking skills should help children be able to analyze the systems around them. The opportunity of gaming in chess can offer a systemic model for merely driving a highly distributed simulation experience and identification of thoughts and choices that align with consistent ways of doing things. With Chess, Scaling up with serious digitally pervasive infrastructure provides a unique opportunity to relook at the classroom ecosystem for digital, game, and technology integration for nurturing children-led aspirations.

Edwards (2013) examines the wider context of integrating technologies with digital games for play-based pedagogies within early childhood curriculum. Lai et al (2014) focus on adding social Elements to Game-Based Learning whilst Abdul Jabbar & Felicia (2015) popularly review game-design feature engagement for facilitating Social Engagement and learning. Nikiforidou (2018) focuses on tailoring practice within the early childhood classroom. Najmeh et al. (2020) discuss the implications of children-centred aspects of health, participation, and contextual engagement for digital gaming experience with the combination of embodiment, active learning, entertainment, and fun. O'Rourke et al (2017) bring insights into commercially available for primary school children digital game technology within classroom applications that are consistent in delivering the fluency of concepts and performance. All, Nunez Castellar and Van Looy (2016) develop an elaborate framework assessing the best practices within digital games to reinforce the understanding of what entails brings performance. In stark contrast, Lai et al (2014) observations on including social actions intervention-type projects have the advantage of being children-led. Georgios et al (2023) explore a complex understanding of playful interventions for sustainability awareness in educational environments. Jie et al. (2020) expand the context of a welfare model to support young people from online Cyber victimization to loneliness and neglect with online digital games. These contexts are useful to be measured across classroom environments with game-based learning approaches.

First, the opportunity to actively scale the outreach of chess far exceeds the notion of exploring the domain knowledge of chess within a rationale of delivering unique learning experiences. The second opportunity however is passively accumulating the gaming experiences that demonstrate an evolution of a playing style that in turn nurtures system thinking experience. Thus, it is of paramount importance to motivate the paradigm of Digital-Game-Technologies within the context of an immersive classroom setting and understand goal-based learning behaviours.

This paradigm delves into exploring four questions on what works within such immersive settings:

1. How do Digital Game Technologies in chess translate to systemic thinking in classroom settings?
2. How do generations of Digital-Game-Technologies-led products shape, organise, and scale classroom participation?

3. How do Digital Game Technologies vary utility from simple digital chess equipment engagement to dynamically configurable adaptive Chess Computers within an immersive classroom setting?
4. How does the communication emerge around the participants and how it is nurtured through an empowering leadership context?

Thus, it is important to examine and illustrate the various positive scenarios to introduce digitally immersive experiences with a generation of digital game technologies for explaining the socio-imagination, usability, and scalability of children-led processes.

2. Settings the Broad Context of Digital Experience with Chess:

The modernizing effort in gaming came with the Digital Chess clock, where Fischer proposed an incremental clock and Bronstein presented a delayed clock to an electronically controlled system of timekeeping to build the first generation of Digital-Game-Technology products into chess. Equally, the sensation of the Internet, the evolution of chess engines and broadcasting technologies, and the adaptation of chess to the internet brought technologies up to date for chess gaining universal access. The context of the triple point of *digital, game, and technology* experience within the constraints of the classroom settings progressively explains the socio-personal contexts of self-motivation, skill-building, co-located engagement, and independent learning and group engagement activities for building systemic advocacy to chess from conventional classrooms to digital immersive space like online, blended and co-located learning environments.

2.1 Context of Gaming Experience: Digital Immersion

Although Chess has reinvented itself into the realms of online gaming and e-sports, the full potential of the *digitally immersive Chess experience* is relatively less explored both within the context of today's available technologies and possible applications within gamification (Chessity.com, 2018). The goal of organising the understanding of systemic thinking in the context of game-based learning is exploited with the understanding of the context of digital for a game of chess. Thus, the deployment of digital technologies for chess has to deliver these multiple utilities in addition to enabling a fair and equitable environment in classrooms. Further, the context of children's engagements within educational settings is expressed in terms of the generation of technologies used with an increasing level of sophistication and computation intensity from a piece of simple digital equipment used for playing, time-keeping, and broadcasting which are passive intelligent systems, to more adaptive Learning systems offering the seamless integration with human perception and machine intelligence.

A conceptual framework evolved with the help of the literature survey is illustrated in Figure 1.

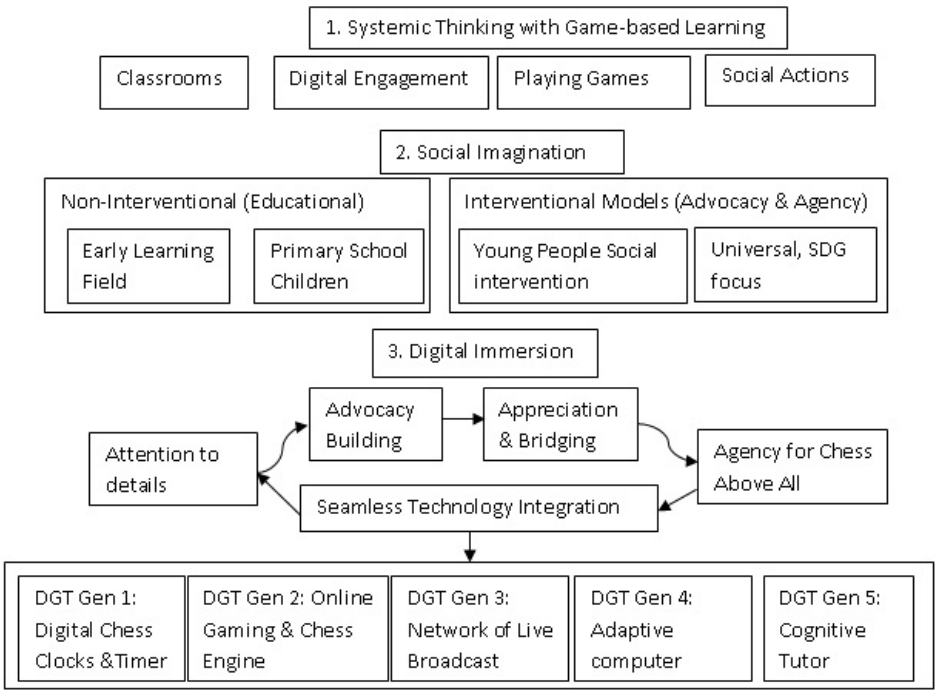

Figure 1: Systemic Inputs for the Digital Immersive Learning Environment

2.2 The Digital Touch for Enhancing Chess Experience

Chess is categorically cast as a mind game, yet Chess pieces selfdom move by themselves on the board. You need the engagement of players to move the pieces around the chess board. This demonstrates a temperament to control the board with the turn-based game with the attempt to shift the equilibrium of each move with the dynamics of play. Although, the game of chess itself is a perfect zero-sum game and has no uncertainty. The digital ways determine the shifting of these dynamic factors more accurately than human perception of the chess position. There is so much computing power in today's chess engine that it surpasses the human ability to accurately arrive at an evaluation based on a forced sequence of moves. Whilst Chess players rely on experience and familiarity in handling the position, computers have better AI searches to summarise move generation. Thus, new opportunities emerge to digitally search through millions of positions and index them with accurate evaluations. Whilst touch is very much the controlled experience in gaming and builds the proactive nature of the Chess experience, the digital touch means the opportunity to unlock and reveal the insight of gaming with AI and Generative AI technologies or it may even amount to impatience to simply look at computer-generated moves for the possibility of right move generation to deepen the opportunity in the position. However, the generation of digital products gives a thoroughly transforming experience through better control and seamless sifting experience across the chess board, computationally exhaustive game trees, automated move and plan generation, and accurate and precision of clock times. Thus exclusive and exhaustive knowledge of chess is reduced to a few impatient clicks on a mouse button with the use of a chess engine on one end. On the other end, chess players have already turned to the effective use of artificial intelligence (AI) for the positive agency for both authoritative and co-creation experiences to direct learning and evaluation of chess position that progressively deepens the understanding. Thus, it increasingly provides opportunity for children and young people to use online, digital equipment, with or without AI-built-in capacity.

2.3 Tangible Gain to Digitally Immersive Classroom Experience

It is of paramount importance to understand that the immersive experience with chess aims to provide a complementary experience of mainstream education and fundamental belief. This is from a rationale that children have prior experience and understanding of the classroom ethos. In such a context, the introduction of the first contact programme for chess and the subsequent opportunity to take the outcome and learning to a whole classroom or whole school is an interesting idea to conceive, however, it is difficult to pursue with rigour. To close this loop, the social imagination of the classroom is considered with engagement across the early-year programme, primary school programme, and young people's engagement in the context of social actions in learning and sharing.

Further social imagination is enriched by expanding access to co-located environments to encourage and nurture both physical outreach and co-located learning. It is also important to understand how they translate this experience back into mainstream education and conserve their agency for digital game technologies. This will start to demonstrate leadership in children and shape how they start to communicate their approach to breaking down complexity, problem-solving, goal-driven development, and systemic thinking.

2.4 Accessibility, Engagement, and Limiting Cases

The response to digitally immersive experiences for people with sensory impairment is fairly straightforward with chess, as reasonable adjustments are available for blind and visually impaired people and deaf-blind communities with the help of adaptive boards.

Further, the inclusive aspect of chess can be harnessed well, if the immersive environments can be understood well and the participation of children and young people from such socially disadvantaged communities can all be carefully integrated without losing their qualities and inequalities.

An immersive experience with chess may additionally offer a therapeutic experience. However, the challenge is continually engaging children's cognitive abilities and masking the disruptive behaviour problems that can disengage them from the classroom.

3. Method

In this paper, a mixed methodology is employed to develop a contextual framework for understanding the top-down approach to deploying digital game technology to achieve engagement goal-driven development. Systemic thinking nurtured an immersive learning environment and social imagination within chess. The emphasis on *what is collectively recognised* as the utility value of the infrastructure in both personal and

shared classroom space will be triangulated based on the 4 research questions that progressively help to understand and construct the digital experience.

A set of the first 6 progressive case studies is examined to understand a divergent view of individual learning experience within a collective and inclusive classroom environment. All the case studies will have a component of *Study by watching, playing games, and Problem-solving as activities as* a bottom-up approach to demonstrate how children collectively harness the access to digital immersive experience and build fluency within the digitally immersive classroom settings. Case study 7 integrates the co-located peer learners both physically and by sharing videos and notes of hands-on work to further feed the social actions and reinforce the group engagement. This strengthens the agency and advocacy for chess as the visitor. Case study 8 integrated the proxy of learners, facilitators, and organisers to observe and report on broadening the impact, scale, and organisation within contemporary thematic programmes like children-friendly approaches, and children-led and women-led empowerment programmes.

An in-vivo observational methodology is employed to further synthesise the understanding of the digital immersion in the case studies to form an evolutionary step towards systemic thinking in the context of (a) advocating children-led activities (b) driving an agency for game-based learning and (c) fluency building and (d) reciprocal interest generating activities to progressively build a *Digitally Immersive Chess Experience*.

4. Results

The activities and outcomes from case studies reporting from various geographical locations are consolidated to understand the context of continuous engagement with chess and its utility value to classroom participation and collective learning as an output.

Case 1 – Mongolian Chess in Schools Aspiration: A unique effort to conserve the international exposure and agency of Mongolian school children who have achieved medals in Asian and World Cadet Championships and within the in Ut-Tsai school programme. The school invested in professional chess assets to set up a SMART classroom to conserve the professional experience with the help of international chess trainers for the agency, a Deep-sea Chess programme for digital advocacy for problem-solving activities for Early-years, and established a zone of proximal development with chess prodigies and professionals. Children collectively maintained professional conduct.

Case 2 – Madrid Chess Academy & CASTLE for ADHD Children: Madrid Chess Academy setup a full professional chess academy with a permanent installation of DGT Live infrastructure to support an outreach with ERASMUS+ CASTLE Project delivering the primary school chess curriculum in Spain with an innovation for the whole-family engagement for children with special education needs. The project achieved a positive introduction to the Case-1 environment and support for the continuous participation of children with ADHD and Autism. Children build a desire to engage with Chess without behavioural issues.

Case 3 – Venezuela and Gibraltar run workshops for creativity education with chess and additionally run a programme especially to support Children with Special education needs. Both workshops were part of an international outreach programme with chess. The main difference is that Gibraltar used DGT Centaur, Adaptive-Chess-Computer, illuminated board within the FIDE Infinity Project Promotion, whereas the Venezuelan academic programme focused on using “PHIONICA-based Gaming Protocols” printed on a Delphi design Chess board. This provided a constructivist approach, enabling skill-mixing, in the context of aesthetics in chess. Children who were visually anchored to the chessboards were absorbed in the workshops.

Case 4 – Welsh Programme with Digital Chess Computer for facilitating children to *independently learn and transfer* activity to incrementally learn to build peer groups. Two DGT Centaur Adaptive-chess-computers were used, during the pandemic lockdown, and two groups were clustered within the community and within school groups, to engage in digital board experience with chess computers. A daisy chain is established to compare the approach with neighbourhood circles and friends in the school to strengthen curiosity and reciprocal thinking. Children communicated their aspirations well with their neighbours about their chess experience.

Case 5 – Problem-solving exercise with online learning for Indian children in the US and India run by Intellect Arena, India with collocated children. To expand a context of conscious, immersive experience online (in Zoom and LiChess.org server), Children with no prior exposure to chess were engaged to build a consistent chess etiquette with a simple paradigm "Learn-Immerse-Value-Engage". Although this focus on fluency and competitive building, the children's engagement was very stable, developed a complementary character, and focused on the transition from a beginner working out around 750 to 1000 exercises within 8 weeks and engaging in 100 games in 24 weeks.

Case 6– Children-led Bridging Experience: With an integration exercise of children, (Physical visit to India and sharing videos of hands-on experience classrooms in Sri Lanka) about self-discovery of DGT Centaur, a digital chess computer operating features, children powerfully self-organised and learn. Children's tendency to influence each other is more with the target group. Children naturally engaged in bridging activity by sharing their insight into exploring DGT centaur and seeing feedback on how others engaged with digital equipment. The Srilankan children continued to work among themselves intensely, 6 of 24 children qualified for the National Chess Championship within just 8 weeks of self-regulated learning and bringing extraordinary performance with chess.

Case 7– Application in an international context for an agency for Digitally Immersive Chess Experience: A women-led community outreach programme to engage digital chess experience, as a skill-building experience that can be transferred to a home country environment based on what works in the context of hands-on experience within an immersive chess festival. In contrast, the stockpile of innovation with digital chess assets in Srilankan schools is tried within the context of women-led for a capacity building programme for implementing a whole region approach as led by the Northern Province Education Department to swiftly replicate cases 4, 5, and 6 in a week to understand and observe the grassroots for the agency for chess. Opportunity connected communities in tandem and bring measurable insights for the advocacy of Women-in-technology for turning to these innovations with the potential to scale on engagement for heavily dispersed refuge communities in the South Asia region and the Southeast Asian region for the promotion of young leaders with an agency for digitally immersive technologies.

Theory of Change	Social Imagination	Digital Immersion	Programme Instances	Incubation/Transfer
(1) Systemic Thinking for Goal-Based Engagement	Young People in Isolation	(3)Social Intervention	**Mongolia/Spain:** Conserving International exposure with chess.	Chess infrastructure for etiquette building
Early Year Field	Children in Primary Schools	(4) Welfare Focus	**Gibraltar/Venezuela**: Drawing to digital immersive design workshops (SEN&D)	Holistic community participation and Immersive experience
(2) Advocacy – Education	(5) Social Action in the context of Classroom experience	(6) Sustainability (SDG4) led a programme for self-directed learning	**Welsh**: Children-led experience Pandemic Diary: Learning and Guideline	Etiquette: Self-discovering, independence & personalised interaction.
US/UK – South Asia & Thailand Cluster: Scalable Context for Women led Designing Safe-space for a social incubator for chess	**Gibraltar:** International Projects students & Women-led experience for Social Actions, and FIDE Infinity	**India/Sri Lanka:** Bridging experience through Children Led instigation & Children's Interaction led Instigation	**India/US**: Online Learning Group, Co-located Learning. (Fluency & Competency building)	Shared aspiration and determination in an immersive setting.
Agency and Reciprocal interest: Incubation supports scale and organisation	Advocacy building: Continuous Engagement	Appreciation: Bridging and Handholding Experience	Attention: Digital to Game(DG) and Technology to Game(GT)	(7)Seamless Integration Digital-Game-technology

Figure 2: Evolutionary Cycles of Digitally Immersive Chess Experience

5. Discussion

There are very few studies in chess seeking to bring an understanding of what *chess-playing children* bring to classroom ethos. The case studies bring a collective exercise for understanding the output of the classroom through proper etiquette building for children and shared incubation of ideas for self-discovering, independently engaging, and personalising the learning experience. The context of understanding Chess infrastructure has become visible in the context of deploying Digital-game-technology for holistic engagement. This offers a systemic engagement as opposed to isolating children based on a single policy intervention of nurturing their innate or acquired talent capital with chess. This was evident from both the extreme case of Mongolian and Madrid for how children regarding their intellectual ability built the agency for chess. This was

also consistent across Gibraltar and Venezuelan implementation when conventional chess boards were replaced with DGT Centaur and Delphi-design. Further, with the bridging case studies across the Diasporas in the UK, India, and Sri Lanka the reciprocal interest in using the DGT Centaur swiftly moved the interest in attending to details to strong performance for developing an agency for chess. Thus, the digital nature of the game of chess is revived within the context of socially immersive experiences for children and young people with seamless integration of digital game technologies. Further, the emerging perspectives of children-led thinking especially looking into the socio-cultural opportunity are interesting from the context of how chess can be seen as a game to grow with for nurturing systemic thinking. Thus, translating these intricate digital designs for harnessing classroom engagement is never-the-less an important convergence for system thinking that is increasingly used in STEM education as positioned by Vuk (2022).

6. Conclusion

The interplay between digital and technologies in the scope of game-based learning is intriguing from a point of transforming the aspiration of children working in such immersive classroom settings. Digital Game Technologies first offers the social imagination for children to progressively nurturing higher-order thinking through hands-on engagements that create an invisible aura for scaling the classroom experience beyond its obvious boundaries. Further, the progressive outputs of case studies bring a useful theory of change by gradually building from the context of positively introducing a digitally immersive chess experience to children-led development for progressively nurturing systemic thinking. The novel implementations built around positive instances of harnessing *digital immersion in classrooms* for purpose build exposure in a social context to develop concept, fluency, and reciprocal learning experience in chess and provide a *Seamless technology-immersive* space for observing children's shared learning environment. The case studies allow insights into what works in the realm of children-led processes that can be contextually scaled without Socio-cultural-economic and geographical barriers.

Whilst, it is still unclear how a holistic engagement alone is sufficient for self-discovery and participation within the immersive setting, as these case study outputs only point to the feasibility of positive hands-on engagement. However, chess in school aspirations need not be delivered so painfully by exerting pressure on the children's curriculum time. Instead, chess can be incubated and transferred into how grassroots engagement can be shaped, scaled, and sustainably organised to satisfactory levels. More research is needed to quantify measurable impacts on a collective adaptation of such classrooms from these progressive experiences.

7. Future Work

Future research opens up in two directions. Firstly, enriching the perspective of the social actions that digital game technology deployment with chess can strengthen for support a uniquely gratifying experience of expanding the context of co-located learners with shared learning experiences. Secondly, the researching perspectives for rightly value-claiming the utility value for these digitally immersive environments for effectively translating to STEM agency and leadership. This will further have implications for the possibility of selecting the candidate technologies with a far-reaching impact beyond the context of acquiring chess etiquette for engagement to empowering educational and social change projects.

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From Research to Prototypes: Developing a Digital Game to Foster Fraction Equivalence

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Abstract: Fraction understanding is a significant predictor of future math achievement. In addition to more traditional instruction, digital game-based approaches have been found successful in facilitating conceptual understanding of fractions (including aspects such as part-whole relations represented as pie-charts, or measurement, i.e., magnitude in terms of number lines). Nevertheless, the number of existing games that address the aspect of fraction equivalence is limited and if so, these typically replicate common paper-and-pencil tasks like identifying and matching equivalent fractions. This, however, hardly takes advantage of the medium's potential and affordances nor strives for intrinsic integration of the learning content with game mechanics. Seeking to overcome this shortcoming, the present article describes the development of a digital game fostering fraction equivalence. To do so, among others, we developed visual animations illustrating the transitions from circular part-whole representations (pie-charts) to magnitudes on a number line—drawing on previous research and games. In particular, a wheel is presented, whose circumference matches the length of the number line which it rolls along. Players can manipulate the number of spikes on the wheel reflecting the number of parts of the whole (e.g., 2 spikes halve the circle, while 4 cut it into quarters etc.). By rolling the wheel, the spikes puncture the number line thus segmenting it into equal parts, essentially transforming the aspects from part-whole relations to measurement (magnitude) on the number line. Additionally, as punctures of 2 and 4 spikes will coincide at the 1/2 - 2/4 location of a 0-1 number line, players can find equivalent fractions. The game under development will be evaluated with late primary/early secondary school students to test its game design, affordances, and possible impact on fraction understanding.

Keywords: Fraction, Equivalence, Development, Education

1. Introduction

Serious Games have been used successfully to assist in teaching, assessment, and learning of mathematics (Pan et al, 2022). Next to practicalities regarding the approaches of serious games' implementation in various settings (home, school, after-school clubs etc.), other important aspects to consider are the mathematical richness of such games, the informed usage of game elements, as well as their appeal to players (Ke, 2008). Math games/apps range from those providing drill-and-practice worksheet-like tasks to those following more common commercial gameplay—with games facilitating fraction learning being no different (Gresalfi et al, 2018). However, they all face the same challenge: on the one hand the need for math games to be built around, and reflect, content of a standard curriculum; on the other, making use and taking advantage of engaging game elements to make the game enjoyable. This important but difficult balance between mathematical content and game elements, has been highlighted in the mathematics education literature (Devlin, 2011), yet is still being explored (e.g., Kiili et al, 2019). While there are practices and frameworks attempting to provide guidance in this regard (e.g., Van Eck et al, 2017), the creation of a generally applicable template for designing a game that is both educationally effective and appealing to learners/players is impossible. Thus, it is important to consider existing math games to identify their advantages and/or possible points for improvement. As such, this article begins with a brief review of fractions as the mathematical content of interest and game elements that foster fraction understanding. Following, a new conceptual idea is introduced for a unique game mechanic to better integrate fraction concepts of part-whole relations (in a pie-chart) and magnitude (along a number line) and show possible facilitation of fraction equivalence. Finally, we describe a prototypical implementation of the new mechanic in a fraction learning game.

Literature review

1.1 Fractions

Fraction understanding is a significant predictor of life prospects more general, and especially future mathematical achievement (Siegler et al, 2012). Simultaneously, fractions are a topic which both students and adults experience considerable difficulties with (DeWolf and Vosniadou, 2015). One origin of these difficulties may be the different—and compared to whole numbers, more complex—representations and concepts of fractions (such as: part-whole relations, magnitude, equivalence, etc.). Area models and pie-charts are commonly used to introduce the concept of part-whole relations to learners (Fazio and Siegler, 2011) often using circular pie-charts, and pizza examples. Importantly, however, it was found that this may lead to potential misconceptions on fraction magnitudes when students only think of a fraction as the shaded part of a whole—such as a pizza slice—and based on this reject 4/3 as a fraction, because of their belief that it is impossible to give four parts of an object that is divided into three parts (cf. Fuchs et al, 2017). On the other hand, number line representations were found to be a more effective approach when it comes to conveying the concept of fraction magnitude, with several benefits, including introducing rational numbers by expanding the metaphor of the number line beyond natural numbers (Sidney et al, 2019). Regarding fraction equivalence, emphasis typically is on identifying and pairing different symbolic representations of fractions—pairing 1/2 with 50%, with 0.5, or with other representations (e.g., Figure 1). Interestingly, pie-charts and number lines can also be used to illustrate fraction equivalence, as equivalent fractions have identical shaded areas or are located at the very same spatial location on the number line. Particularly, segmentations of pie-charts or number lines (e.g., into halves and/or fourths) may be presented to scaffold how the areas/locations of 1/2 and 2/4 are aligned.

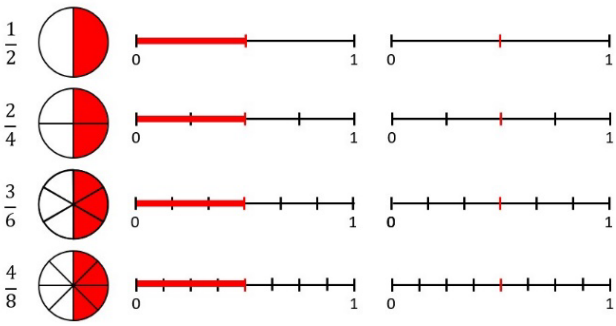


Figure 1: Fraction representations. Symbolic, part-whole, magnitude as length, and as a point on the number line (from left to right)

1.2 Game Elements

For a more comprehensive understanding of the game-based learning literature as well as the added complexity of designing a learning game, it is crucial to consider the fundamental components of a game (cf. Plass et al, 2015). The foundation of each game is its *game mechanics*, which determine player interactions with the game, such as the way a game avatar is controlled/can be moved/etc. In addition, *visual* and *musical* art are used to convey information about the game environment through the senses, while *incentive systems* like points or collectibles are implemented to motivate players. Additionally, the game's *narrative* ties the gameplay together into a cohesive story. These five elements (game mechanics, visual and audio aesthetics, incentives, narrative) can be combined in various ways to create a game, depending on the resources and design available. However, for games specifically focused on educational purposes—and in our case, games for fostering fraction understanding—the educational content is an additional crucial element. This content must be effectively conveyed through all the other game elements to support learning. While some research has criticized the use of game elements in education for potentially distracting students if not done properly (Mayer, 2020), other studies suggest that aligning game and learning mechanics can lead to successful learning outcomes through *intrinsic integration* (Habgood and Ainsworth, 2011). But what about existing games fostering fraction learning?

1.3 Game Elements Fostering Fraction Understanding

The relevance of intrinsic integration was particularly highlighted by a systematic literature review on games for fostering rational number understanding (Kiili et al, 2019). The review indicated that there is an apparent lack of intrinsic integration in most of the existing games to foster fraction understanding, meaning that the learning content of fractions was not integrated effectively into the gameplay through the game mechanics of the respective games. Nevertheless, number line games were most prevalent in the review, with the mechanics

including ordering, comparing, and estimating—depending on the game and the tasks covered in the respective studies. Players typically have to estimate the location of a fraction on the number line (see Figure 2 for a generic illustration of elements used in such games), or otherwise work with fractions and their magnitudes, which often appear in their symbolic a/b (often along their decimal or percentage forms, i.e., 0.5, 50%) but also non-symbolic representation (e.g., pie-charts, area models, etc.).

Operating upon the number line—the characteristic feature of such games—is one more element they share. In particular, the movement mechanics, either of an avatar or other physical objects that are manipulated by the player. Occasionally, this movement is accompanied with a jumping or bouncing ability which expands to other systems (e.g., jumping over traps or as a way to estimate a fraction's magnitude upon landing). As highlighted in the review, *feedback* is another very important occurring element in these games. *Immediate feedback*, when players move their in-game avatars, by updating their location, as well as feedback upon whether their estimation was close or far from the position of the target fraction on the number line: Depending on the game and the difficulty setting (Gresalfi et al, 2018; Ninaus et al, 2017), the game will indicate various degrees of success. For instance, more incentives offered when closer to the estimation or hints that will be given for extra attempts for estimating the same fraction—to scaffold the learning process as well as to adapt the progression of the game to players' needs and performance (e.g., game avatar being happy/sad if close to their estimation).

Additionally, *corrective feedback* is used in a lot of these fraction number line estimation games indicating the correct position of the respective fraction on the number line after the player provided their estimation. Common gameplay loops involved in these games are: i) a target fraction is presented on the screen to be estimated by the player (e.g., "b" in Figure 2). After the player estimates its position on the number line, ii) another target fraction appears, is estimated, and so on and so forth. In case the game is designed with corrective feedback, after the player estimated the respective target fraction, its correct position on the number line is indicated by the game (e.g., by a short vertical mark, revealing the hidden position, e.g., "f" in Figure 2). This seemingly simple game design reflects the mathematical learning content intrinsically, as it represents fraction magnitude as a relative length on the number line (i.e., "3/4 goes here on the number line"), as well as the distance between players' estimation and the correct position (e.g., "you were this far off/close").

The effect of feedback may be magnified when accompanied by other mechanics—such as virtual incentives. For instance, a point-incentive system is often used awarding points based on estimation accuracy and thus directly linked with the above-mentioned degrees of success—to increase players motivation. Moreover, a more summative overall grading is often used, such as awarding stars for reaching a certain threshold (e.g., upon level completion with a certain mean accuracy/a certain number of points awarded etc.)—which seems to be especially appealing and driving for young players (Thoma et al, 2023). Finally, the game elements are typically embedded in a narrative to tie them together in a coherent story to immerse the game play. For example, a dog digging for bones that a cat has hidden along a number line (e.g., Koskinen et al, 2023), a hero digging for gold coins (e.g., Kiili et al, 2018), or a ball bouncing higher with every correct estimation (Riconscente, 2013).

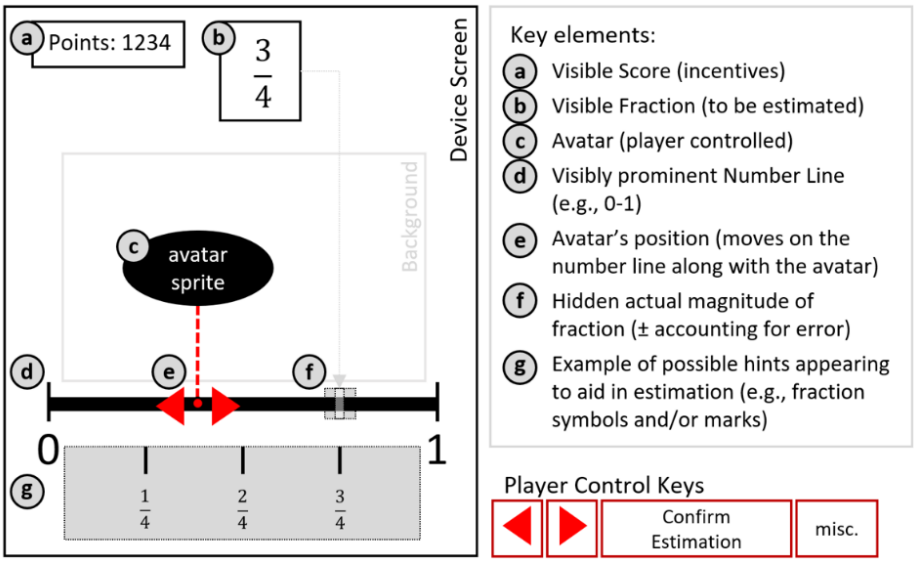


Figure 2: Generic illustration of a fraction number line estimation game

In sum, through the i) integration of game mechanics (i.e., movement on the number line, various levels of feedback), ii) clear visual representations (i.e., position of avatar reflecting fraction magnitude on the number line, corrective feedback), iii) a narrative (e.g., gold or bones hidden in positions on the number line), iv) incentives (embedded as measure of estimation accuracy, extrinsic star system) all these link to—and are designed based on—the mathematical content of fractions (reflected as magnitudes on a number line).

2. The Current Prototype

Considering the aforementioned, the aim was to further develop and combine above-described game elements to create a new number line estimation game that—among others—facilitates a comprehensive understanding of fractions to better illustrate fraction equivalence. In this manuscript, the focus is on the central game mechanic we developed to foster the integration of the fraction concepts of part-whole relations and magnitude to then facilitate understanding of fraction equivalence. As mentioned earlier, available games or apps (e.g., Gresalfi et al, 2018) typically approach the aspect of fraction equivalence primarily via the identification and association of fractions (e.g., 1/2) with their equivalent counterparts in a list (e.g., 1/3, 2/4, 2/6, etc.) or other representational formats, such as pie-charts, by selecting, matching or pairing them together. From a mathematical perspective these are indeed the fundamental skills related to fraction equivalence. On the other hand, these actions are usually not well-integrated with other fraction concepts in games. This might prevent a comprehensive understanding of fractions across concepts like part-whole, magnitude, equivalence, etc. and in turn facilitate common misconceptions mentioned in the literature.

Firstly, we conceptually introduce the new game mechanic allowing us to better integrate the concepts of part-whole relations and magnitude of fractions—called for descriptive simplicity, the *wheel of fractions*. We later outline how it can be applied to specifically facilitate the concept of fraction equivalence. For both aspects, we will first describe the conceptual background before outlining its prototypical implementation in a game. The prototype's latest version is available at: https://spoonsweet.itch.io/felis-fractus.

2.1 Wheel of Fractions—Conceptual Background

2.1.1 Length

To better understand the mechanic used in the game it is necessary to introduce the underlying conceptual idea. The important aspect that allows the wheel of fractions to work as a transition tool between part-whole relations and magnitude, is the dimension of length. Length, appears in two forms: i) as the circumference of the wheel, and ii) as distance from 0 on the number line (Figure 3). Hence, a design is required where the wheel's circumference matches the length of the number line which it rolls along. Consequently, as the wheel rolls along the number line, any part of the circumference is equivalent to the respective length on the number line (e.g., rolling the wheel for 3/4 of the circumference will take you 3/4 of the number line, Figure 3a).

2.1.2 Area

Transferring this idea to area models is important for visual communication. As mentioned in the literature, it is usually sectors of the wheel that represent fractions as a pie-chart, as these are visually more distinguishable than their arcs. Therefore, in the wheel mechanic, it is important to showcase this representation of sectors as parts of the whole of the wheel. The dynamic use of colour helps illustrate the transition animation, (as depicted in Figure 3b,c,d).

2.1.3 Segments-spikes

Another bridge between the two representations becomes evident by introduction of the circle radii. Radii are typically added to showcase a fraction as segments, meaning parts of a whole, for instance, "3 shaded parts out of 4" (Figure 3c). Comparable to the segmentation of the wheel through radii, it is possible to segment the number line. For the prototype game mechanic, the length of the radii is extended to create a spiked wheel. By rolling the wheel, these protruding spikes puncture the number line, segmenting it into equal parts (Figure 3d).

To conclude, the rolling animation of the spiked wheel, allows the visual and mathematical integration of the fraction concepts of part-whole relations and magnitude on the number line, at the same time carrying over all the supporting elements of length, area, radii/segments.

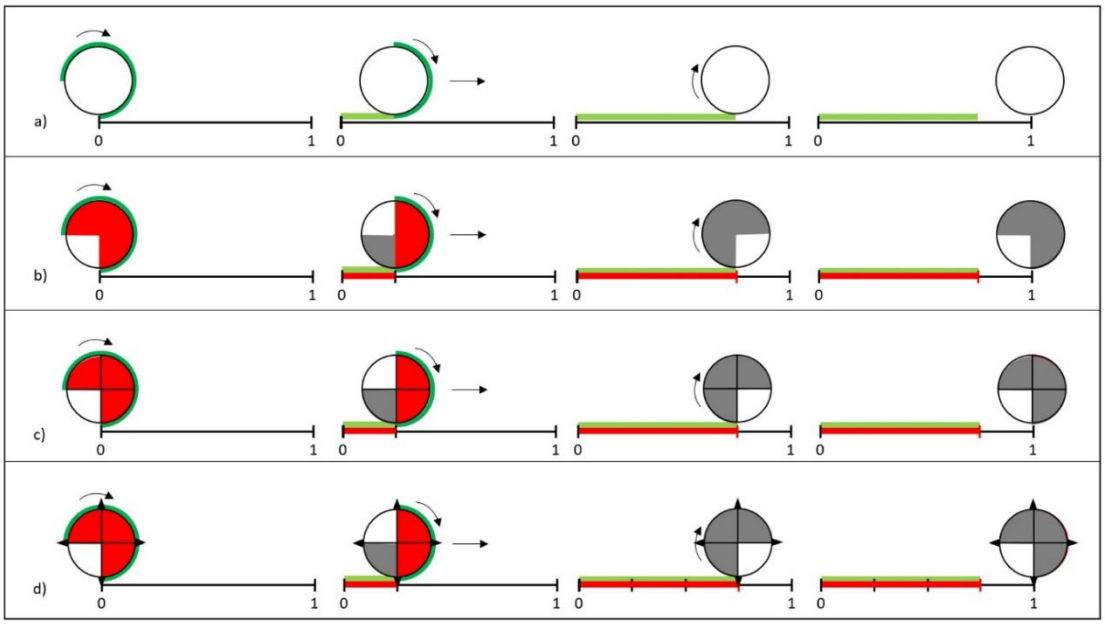


Figure 3: Schematic illustration of the wheel rolling. a) Example 3/4, of the conceptual idea with the circumference turning to length, b) transition of area/colour as the wheel rolls, c) radii and sectors, d) the spikes segment the number line by rolling across

2.2 Wheel of Fractions—in a Game

Designing and prototyping the wheel system in a game, allows for a variety of in-game tasks and affordances, some of which are presented here. All the above-mentioned parts of the system are used in the game, either separate or in an interconnected way. In the following, we first describe the implementation of the wheel of fractions mechanic conceptually, expand on more complex systems (Figure 4), before we present first playable prototypes (Figures 5 and 6).

2.2.1 Dynamic segments and systems of equivalence

The initial creation of the wheel system was to accompany the original number line fraction estimation tasks (e.g., Figure 2), by offering a dynamic segmentation system to the player. By manipulating the number of spikes in their wheel, players can partition their number line in equidistant segments, which aid them in future estimations. As already seen in Figure 3d, a wheel with four radii, would segment the number line in quarters. If a player wishes to change the segmenting to fifths, they can retract the wheel, add an extra spike, and roll it again. For visual clarity, upon retraction of the wheel, the old marks are cleared from the screen.

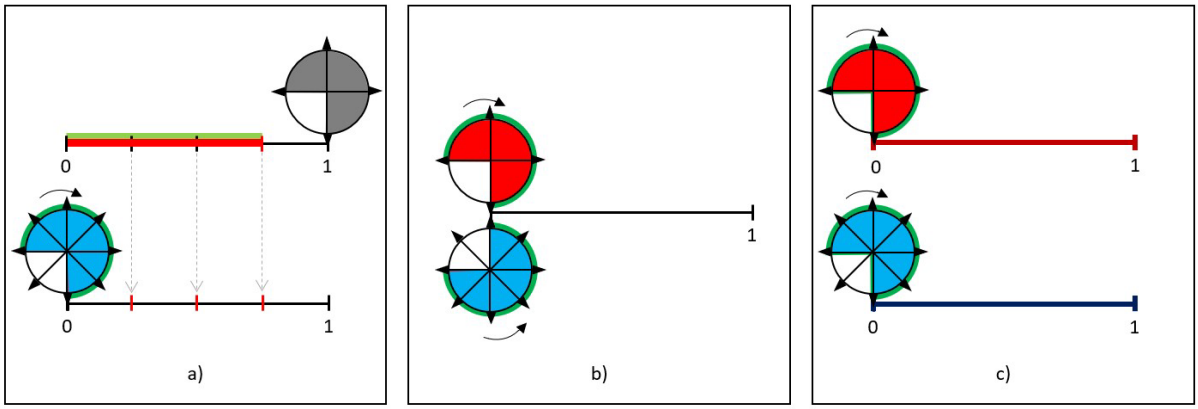


Figure 4: Equivalence with wheel systems. a) One after the other two wheels are rolled on the same number line, b) one number line is punctured simultaneously from top and bottom, c) two wheels are rolled on two parallel number lines

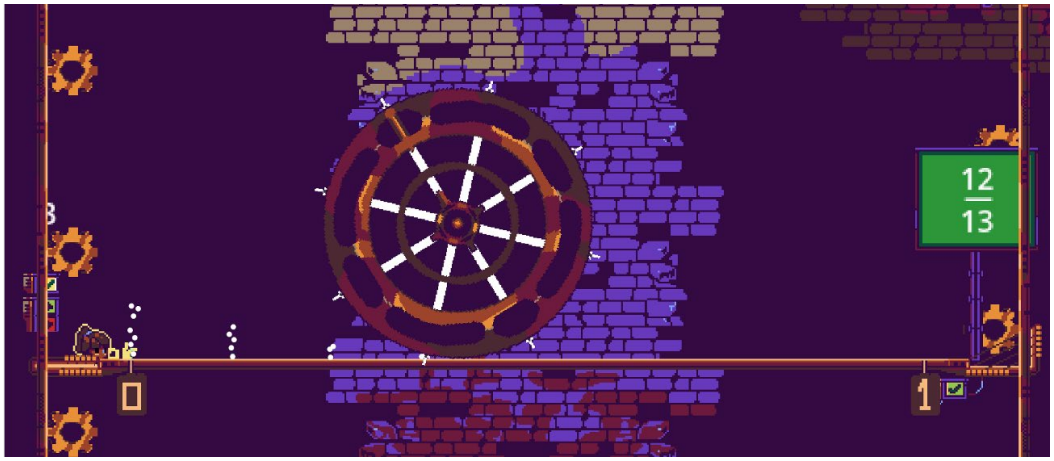
However, there also are ideas being explored where past segments leave a trace (e.g., with a lower opacity, different colour/shape) allowing the comparison of segmentations and magnitudes. For example, a series of red punctures could signify the segmentation in quarters while blue punctures could reflect eighths (Figure 4a). As

one of the main aims is the focus on fraction equivalence, this would assist in illustrating that equivalent fractions share the same magnitude. The panels in Figure 4 depict this idea in three different implementations. Using the magnitudes of the above Figure 3 example, different colours are used here to help with it visualization. In each panel, a different system is explored. In Figure 4a, the wheel has been rolled once, and the number line segmented in quarters. Leaving the punctured segments in-place, the wheel is retracted and armed with a total of eight spikes. When rolled for the second time, some of the new spikes—specifically the ones at 2/8, 4/8, 6/8—would fit at the already existing punctures, from the quarter segmentation. Figure 4b, shows a combined system of one number line being punctured from top and bottom simultaneously, essentially creating paths at the equivalent positions—since punctured at both ends. Finally, in Figure 4c, two parallel number lines are positioned in such a way, that equivalent fractions would be aligned in their respective positions.

2.2.2 Punctures and their usage implemented in a game

Implemented in a game, each puncture on the number line offers a visible mark (Figure 5a,b). This can be used by players in the ways mentioned above (as segmentation of the whole and connecting equivalent fractions), but also allows for existing game mechanics to be enrichened. For example, as noted in the literature, fraction magnitude is usually estimated by the player, by moving an avatar to a specific location on the number line starting from 0 (e.g., Figure 2, or Figure 6 for the prototype estimation). This can be enhanced with a new mechanic, where the avatar is designed to drag a ribbon or elastic band from the 0-mark with the option of securing it in any of the puncture-marks. Thus, the respective magnitude may be reflected explicitly (Figure 5b). With this action, the visualization gives the magnitude on the number line a second dimension, i.e., length, in addition to being a point on the number line (as shown in Figures 1 and 2). This dragging mechanic gives the opportunity for players to "shade-in" the number line, and experience magnitude as length from 0 to the desired position. Depending on the actual task design, this affordance may be implemented as just described (Figure 5b) or be integrated with the wheel system, unravelling automatically (as indicated in the abstract Figures 3 and 4a).

a)



b)

Figure 5: *Wheel of fractions* in-game. a) Armed with 8 spikes, the wheel rolls across the number line. b) Dragging the elastic band mechanic. From 0 towards the 3/8 puncture

2.3 Supportive Game Elements

2.3.1 Spikes as a resource

Acquiring spikes to add on the wheel can be directly linked to the incentive and narrative game elements. In our case—building upon the foundation of a fraction number line game—the concept of point-incentives for successful estimations can be embedded mechanically and narratively. For instance, estimating a fraction magnitude successfully (e.g., with ≤2% estimation error) would reward the player, not only with score points, but also with a high-value in-game artifact. This collected artifact, could then be used to form a spike to arm the wheel. For example, playing the game, a player estimates fractions with varied levels of success. At some point, they manage a successful estimation above the threshold (e.g., ≤2%) and are awarded with an artifact. After it is formed to a spike, it arms the wheel, the wheel is rolled, and the player now sees how the wheel system works. After a second successful estimation, the wheel is armed with another spike, rolled over, and the number line is segmented into halves. Now the player can estimate fractions more accurately since they have a clear reference of 0.5. With more successful estimations, more spikes are collected and can be used on the wheel, to segment the number line , allowing for more targeted estimations, which should lead to more successful ones—and eventually—more spikes. Interconnecting the two systems this way creates two gameplay loops that feed into each other: i) estimating fractions to collect spikes, and ii) arming and rolling the wheel to improve future estimations. This interconnectedness should keep gameplay interesting, add complexity, give agency to players (as their actions have impact and direct improvement to their future estimations), and allow for strategy (of choosing which and how many reference points), all of which are beneficial aspects known to keep players motivated and continue playing (Plass et al, 2015).

2.3.2 Overarching narrative

The above-described game mechanics and elements only become fully effective when integrated into an overarching narrative that incorporates these different aspects into one coherent game. The idea for this narrative is as follows. The game takes place in an underground sewer system. At the bottom of the sewer system, in the acid waters, laser-cats swim (Figure 7). The player, through their avatar, will be invited to restore and redevelop the underground village civilization. To do so, players will have to collect energy from the laser-cats. When excited, a laser-cat shoots up from the depths in a straight line (Figure 6b and 7a). If the player has proper equipment (i.e., specific in-game thresholds have been reached), they can capture energy from the cats by estimating the position they are going to shoot up on the number line. Captured cats can later be repurposed as an energy source in a lab, reinforcing the narrative and creating more gameplay loops.

a)

b)

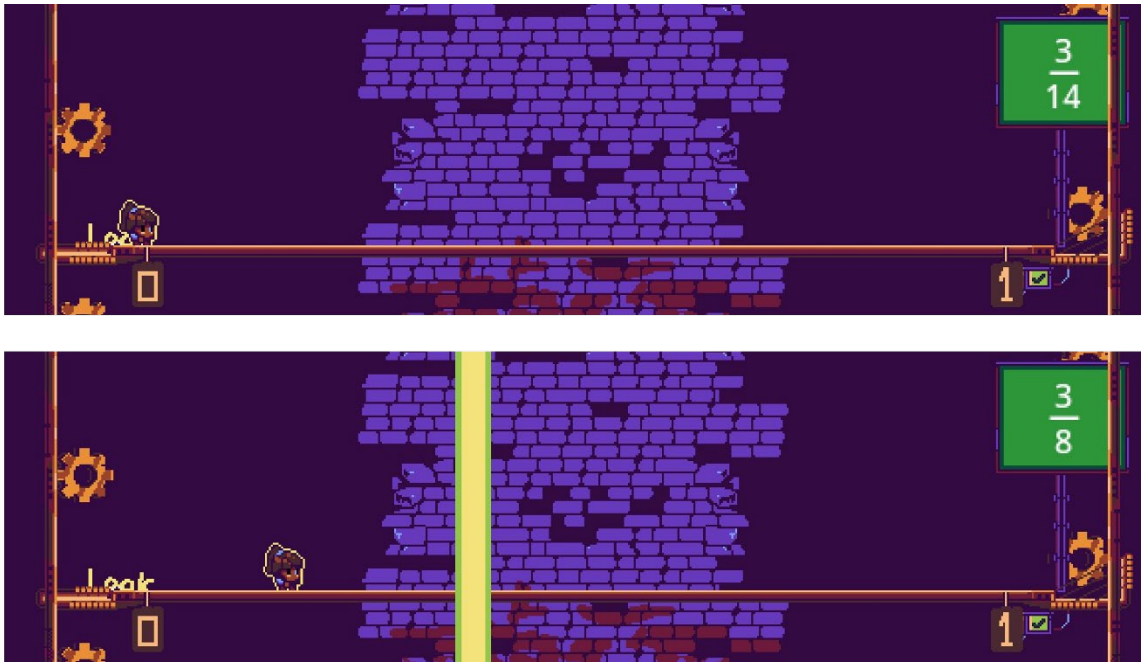


Figure 6: The prototype. a) Basic elements of a fraction estimation number line game. b) Corrective feedback indicates the position of the 3/8 fraction magnitude

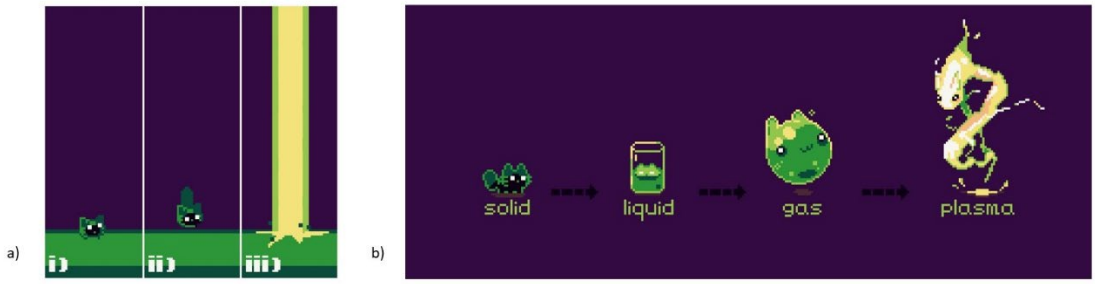


Figure 7: Laser-cats. a) Animated cat's laser trajectory as corrective feedback/magnitude on the number line, b) states of cat matter concept art

Aiming for intrinsic integration, each activity taking place in the game is designed towards fraction understanding and especially aiming towards fraction equivalence. As such, laser-cats' existence is multifaceted and embedded to all the aforementioned systems and mechanics. Firstly, as in-game objects, each cat spawns with a fraction magnitude between 0-1. This magnitude will be descriptive of each cat, and accompany it in the game through the various tasks. On the number line, from a mathematical perspective, a laser-cat's trajectory is vertical to the platforms (Figure 6b) working as corrective feedback on fraction number line estimations. Their laser properties allow them to fire upwards throughout the sewer system, with the possibility of simultaneously hitting numerous parallel platforms, assisting in fraction equivalence (e.g., as described above in Figure 4c). Cats are also incentives on the number line. If the player estimates their position correctly—meaning their avatar is literally inside the blast zone (Figure 6b)—energy points are gained. In case the estimation is successful (e.g., ≤2%), the cat is also captured as an artifact—and can be armed as a spike for the wheel (Figure 5). Otherwise, if taken back to the village, can be used for other narrative purposes after being stored as batteries in bottles (Figure 8c). This bottling of cats, works through a mini-game, which awards and reinforces fraction representations: in lab equipment screens, the cat's magnitude will appear symbolically, then on a short number line, and after that, on a pie-chart (Figure 8a,b), whereupon the player will have to confirm the representation with simple button presses. This way the cat will be stored as a battery, and simultaneously registered in a bestiary. This will reinforce not only integration of the different representation formats, but also allow for an in-game encyclopaedia showcasing all the fractions captured. As such, equivalent fractions will be logged in the same entry (e.g., 5/11 = 10/22), considering additional game elements to increase mathematical depth.

Figure 8: Bottling cats mini-game. a) The player has to align a moving mark with the desired fraction magnitude on the number line, b) and a rotating mark on the pie-chart, c) concept art of the lab.

3. Discussion

The aim of this article was to introduce a new game mechanic allowing for the integration of fraction concepts of part-whole and magnitude as well as applying it to facilitating the understanding of fraction equivalence. This

wheel of fractions—synthesized as a wheel whose circumference matches the length of an associated number line—reflects part-whole relations as known from pie-chart representations. While common in introducing fractions, pie-charts were also found leading to some misconceptions about fraction magnitude. Thus, we aimed at facilitating the transition between this pie-chart representation and the concept of magnitude as represented on a number line—a representation format known to be fostering number magnitude understanding. By extending the radii that segment the wheel, spikes are formed. When the spiked wheel is rolled across the number line it punctures and thus segments the number line into equal parts allowing for an integration of the fraction concepts of part-whole and magnitude. Embedding the wheel mechanic in a fraction number line estimation game further allows for illustrating equivalent fractions—for which, different numbers of spikes puncture the number line at the same position. This gameplay loop may be fuelled by other game mechanics such as virtual incentives and an overarching narrative corroborating the mathematical richness of the game. Even though, the conceptual idea of the wheel is of compelling simplicity and apparent validity, empirical studies are needed to evaluate the usability of the game—and its specific game elements—as well as its educational effectiveness in terms of fostering fraction (equivalence) understanding.

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Values-Based Transformative Games: From the Physical to the Digital

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Abstract: In the context of game-based learning, learning is often limited to basic literacies such as math and reading, even though several educational institutions acknowledge the importance of Values education. In this paper we discuss how to bring values into a game. We discuss the design and implementation of a customisable version of the popular board game, Snakes and Ladders to teach values to the young (ages 0-8). Values refer to "a centrally held, enduring belief which guides actions and judgements across specific situations…". This implies that there is an inherent element of choice or decision-making in demonstrating one's values. We discuss the process of adapting the Snakes and Ladders board game to a physical artefact by applying a Values-based Transformative Games Design Model, and further digitizing the artefact to make it more accessible. A prototype of the digital artefact is presented to demonstrate the concept. The Insider Action Game Design Research methodology is applied to create a physical artefact given the researcher's involvement in volunteer work on values-based education for the young. The findings of this research are of immediate benefit to those wishing to introduce a digitized version of a simple and popular board game to teach values to young children. The values-based questions used in the game are easy to adapt so the game has the potential to be extended to various other basic literacies, as well as different types of values such as sustainability and cultural values. The Values-based Transformative Games design model can also be adapted and improved with further research.

Keywords: Values, Transformative games, Young, Serious games, Sustainability, Game design

1. Educational Board Games

Educational board games are a popular and timeless means of teaching players whilst having fun. Human beings learn best from play and taking advantage of collective intelligence, the two qualities of most educational board games (Mackay, 2013). Educational board games are also available for all ages, making them versatile, highly accessible and collaborative.

Popular educational games are designed to train players in areas such as Maths, Reading, Science and Strategy. More recently, researchers recognise that educational board games have the potential to lead players into taking action in their communities in areas such as wellbeing and sustainability (Mulcahy, Zainuddin and Russell-Bennett, 2021; Pope, 2021) i.e., transformative. Boardgames represent a subset of ludic artefacts, defined as objects of play which require players to directly interact with them in order to produce their narrative effect (Bos, 2018). Van Delden (2019) concludes that the immersion in board games can be really high, an often used argument for applying new technologies. Board games simultaneously allow for social facilitation (cf. Marks (1998) remark about Risk that the computer-mediated game might actually hinder social facilitation). They argue for effect studies of possible immersion combined with the recent rise of cooperative against board games. In essence, normal board games can have an educational value but transformational board games can have much more value.

We acknowledge this power of educational board games and we propose that educating for action or transformation requires a focus on the *values* of a player (section 2). Spil and Bruinsma (2016) introduce the Value proposition game based on Osterwalder and Peigneur model (2005), a card game to determine the future value of a game idea. Determining value in an early stage of creating the serious game helps in reaching the goals later.

In this paper, we discuss the design and implementation of a values-based and customisable version of the popular board game, Snakes and Ladders. We demonstrate the application of a Values-based Transformative Games Design Model (section 3) to create both a physical artefact (section 4), as well as a digitized artefact (section 5) adapted from the Snakes and Ladders board game.

The findings of this research are of immediate benefit to those wishing to introduce a digitized version of a simple and popular board game to teach values to the young. The actual values-based questions used in the game are easy to adapt so the game has the potential to be extended to various other basic literacies, as well as different types of values such as sustainability and cultural values. Practitioners such as game designers can also apply the Values-based Transformative Games Design model for other types of games, both physical and digital. Last, but not least, researchers can further validate the Values-based Transformative Games Design model, as well as enhance it with other game design constructs not considered in this research.

2. Values Education for the Young

The concept of values has been suggested as a core concept across all the social sciences (Allport, Vernon and Lindzey, 1960; Rokeach, 1973; Schwartz, 2012), and is used in a variety of contexts – personal, family, organisational, and societal. In the personal context, we can define values as "central desires or beliefs regarding final states or desirable conducts that transcend specific situations, guide the choice and evaluation of our decisions and, therefore, of our conducts, becoming an integral part of our way of being and acting to the point of shaping our character" (Schwartz & Bilsky, 1987) in (Argandoña, 2003). This is a social psychology perspective on values. Similarly, Rokeach (1973) views a value as "a centrally held, enduring belief which guides actions and judgements across specific situations and beyond immediate goals to more ultimate end-states of existence". This implies that values do not change too much over time. Researchers on values also explain that these beliefs guide us across our various life situations, and that they are different to other psychological constructs such as traits, norms, needs, preferences, worldviews and roles because there is an element of choice or decision-making in values (Marini et al., 2018; Schwartz, 2012).

In this research, "the young" refers to those between the ages of 0 to 8 years old. According to UNESCO, this may also be referred to as early childhood, a period when remarkable brain growth takes place, laying the foundation for subsequent learning and development (UNESCO, 2015). Researchers find that children begin to absorb values early on in life (Halstead and Taylor, 2000) and that we probably develop a moral sense within the first two years of life (Kagan and Lamb, 1987; Buzzelli, 1992). This is closely linked with emotional and social development (Dunn, 1988; Kuebli, 1994) in the young, which is a crucial factor in our long term well-being. Since play and learning are intertwined aspects in a young person's life, most of this learning takes place during play. A lot of the literature on the young is therefore centred around play. In fact, research has found that play takes the shape of a ''didactic device", such that to an extent, our identity also depends on the games we played in our childhood, and on how much we played (Farné 2005).

This research acknowledges that the best medium to provide this education is through play, and that the prevalence of digital mediums for play present a good opportunity to provide values education to the young.

3. Values-Based Transformative Games Design

In this section we present a model to design values-based transformative games (Tilvawala, Sundaram and Myers, 2019). The model outlines various levels of game design when the objective is to foster and sustain a value in a player. These levels are represented as parts of a model where one level leads on to the next. For example, if you want the player to learn the value of conserving energy, it is important to first *educate* the player on why conserving energy is important, then engaging them in a scenario to recognize how energy may be conserved. This engagement helps them appreciate this value and hence persuade them of its importance. Next, the player has the opportunity to reflect on their own practices in the real world and make decisions in the game, based on these practices i.e. subtle changes in a player's decision-making process. The more a player *practices* and acknowledges the importance of the value, it becomes a habit. This leads to *transformation* in the player's values. The goal is to take the player through these levels, and even iterating within each level to transform and *sustain* the values being learnt through the values-based digital game.

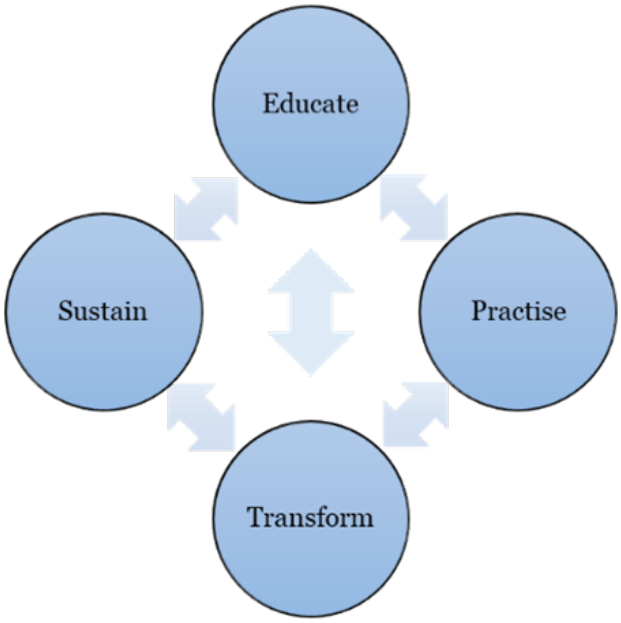

Figure 1: Values-Based Transformative Games Design (Tilvawala, Sundaram and Myers, 2019)

4. Physical Artefact

The objective of this research is well suited to be first explored using a physical artefact, followed by the creation of the intended digital artefact. The intention is to leverage the experience, feedback and observations of designing and implementing the physical artefact to guide the design and implementation of the digital artefact.

The value of having physical artefacts prior to digital artefact design are multi-fold. In this research context, the foremost role of the physical artefact is to validate the artefact with the target users, in this case, the young.

We apply an Insider Action Game Design Research (Figure 2) methodology (adapted from Jrad, Ahmed and Sundaram, 2014), a combination of Action research, Design Science and System Development (Nunamaker, Chen and Titus Purdin, 1991; Avison *et al.*, 1999; Hevner *et al.*, 2004; Sein *et al.*, 2011). This methodology is of particular relevance given the researcher's involvement in volunteer work in values-based education for the young.

Design input may be gathered via observation. The physical artefact also acts as an iteration of design science research as per the guideline of viewing design as a search process (Hevner et al., 2004). Another objective of this research is for the digital artefacts to influence players' values in the real world. The physical artefact helps assess this objective with a more tangible artefact, and the ability to view players' reactions and progress in the game in person. Further, the learning from the process of creating the physical game artefact also contributes to the process for creating the digital game artefact. Nuances in the game content, mechanics and logic are easier to observe across a larger target user group for rich, collective feedback in a physical setting. In essence, the physical artefact is another perspective of the game, to aid in a more robust game design (Schell, 2014).

Next, we discuss the four phases of creating the physical artefact – observation, theory building, game development and evaluation.

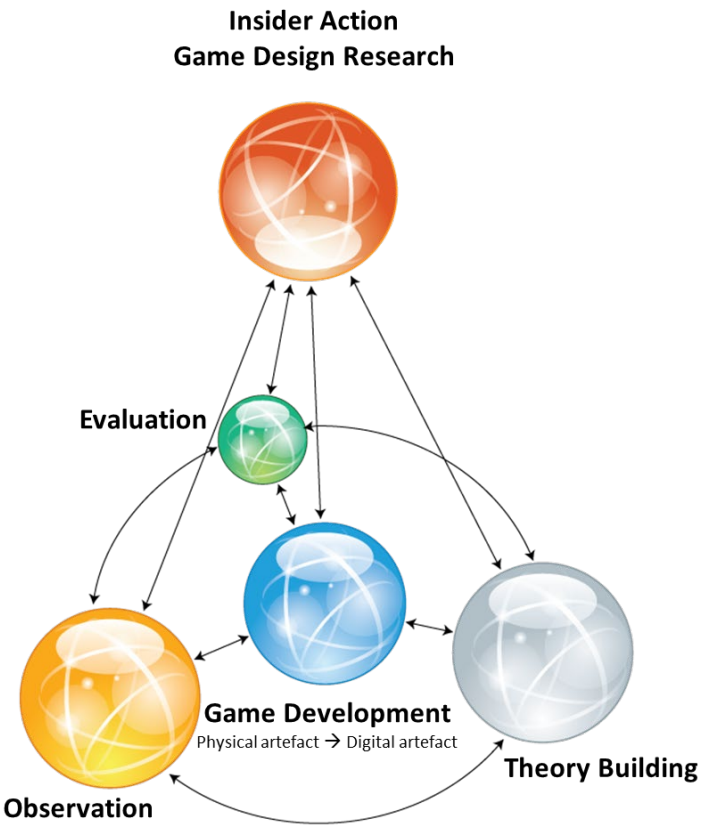

Figure 2: Insider Action Game Design Research: From the physical to the Digital (Adapted from Jrad et al., 2014)

4.1 Observation

The objective of observation is to gain a general understanding of the research area, to understand the factors driving the research decisions (Nunamaker, Chen and Titus Purdin, 1991).

The researcher's role as a volunteer at a values-based school was observed to be in synergy with the efforts to create conceptual and system artefacts to guide the design and implementation of values-based games. The idea to design a physical values-based game for the children to play and engage with came about as part of the general activities at the values-based school. The researcher played a more active role in this process after this objective was outlined. First, the options for the game were brainstormed. The group was assigned approximately 30 minutes to play the game, there was also a readily available checkered playground floor, and the age group assigned for this activity were 5 to 6 year-old children.

Given these considerations, the consensus amongst teachers planning the activity was to design a life-sized board game for play. Several popular board games were shortlisted, including Ludo, Tic Tac Toe, Snakes and Ladders as well as memory games like Go Fish. Snakes and Ladders was eventually the unanimous game of choice given its familiarity and easy to follow rules.

One of the criteria when selecting the game was for the rules for be straightforward and easy to understand for a 5 to 6 year-old child. The purpose of the game was to reinforce some everyday universal values that the children were familiar with while having fun, so they do not spend too much time understanding the rules of the game, but instead, stop and think about the consequences of decisions (values-based).

Research about the history of the game further convinced the team of teachers working on the live sized game of its suitability. Snakes and ladders is an ancient Indian board game with roots in morality where the player's progression up the board represented our complex life journey made of virtues (ladders) and vices (snakes) (Augustyn, 2004). It is also commonly used to teach basic literacy to children e.g. counting, basic addition, sequence and patterns of numbers (Newmonic, 2016). For the life-sized game, the goal was to leverage Snakes and Ladders to reinforce positive values by demonstrating the consequences of practising these values via the day-to-day decisions we make. The idea was to go beyond basic literacy, and these goals somewhat aligned

with the roots of the game where ladders depict the positive and snakes depict the lack of positive. The next section discusses how Snakes and Ladders is designed for the purpose of this research.

4.2 Theory Building

At a macro level, the objective of theory building is to develop new ideas and concepts, including conceptual models or frameworks (Nunamaker, Chen and Titus Purdin, 1991). The purpose of these "theories" is to guide the design of the system as well as to guide the observations. In this research, the application of the Values-based Transformative Games Design model (Figure 1) is assessed. The model has four parts – Educate, Practise, Transform and Sustain. The physical game aims to "educate" the players, in this case, 5 to 6 year-old children about some universal values. In this instance, it is assumed that the children are already familiar with these values and the game will help reinforce these further.

The execution of this game and observations of the physical game being played help guide the design and implementation of the digital artefacts, much like an iteration in design science research (Hevner *et al.*, 2004). Further, the physical artefact itself contributes as another medium for children to learn about values, a complementary artefact to the digital artefacts envisioned in this research.

In essence, the purpose, vision, and rules of the physical game are the same as a potential digital game, but its execution, scalability, portability, and experience change with a digital medium. To exemplify this theory, the physical game of Snakes and Ladders is designed into a live sized values-based game for children. The teachers chose to include some universal values for this game (Schwartz and Bilsky, 1987; Schwartz, 1992). The objective was to exemplify the universal values via scenarios for "Snakes" and "Ladders" in the game, where "Snakes" represented scenarios where a value was lacking and "Ladders" where a value was present. The presence of these values would mean progressing faster through the game, and the lack of the value would slow one's progress. The scenarios for the "Snakes" and "Ladders" were carefully worded and reviewed a few times and adapted these to ensure they were neutral to all cultures and not introducing an undesired or negative value through the game.

The next section discusses the implementation and execution of the physical artefact.

4.3 Games Development

The objective of the game development phase is to test the feasibility of the conceptual artefacts proposed earlier via the design and implement a physical values-based game (Hartmanis, 1993). The artefact that results from system development then functions as a bridge between the technological research (concept stage) and the social research (impact stage) (Nunamaker, Chen and Titus Purdin, 1991).

The Snakes and Ladders game in this research is created as a design iteration for a digital values-based adaptation of the popular game Snakes and Ladders. The activity encourages positive values in 5 to 6 year-olds by taking them up the ladder for eliciting a positive value, and down a snake for a negative value, or lack of a positive value. The activity was planned such that children played on a live sized snakes and ladders board, which was hand-drawn based on a typical Snakes and Ladders game board (Figure 3). The list of values-based scenarios brainstormed in the theorising phase were prepared into chits to be handed out to the players every time they landed on a Snake or Ladder. The rules and mechanism of the game remained the same, with the added layer of the chits to reinforce the values by providing a reason for either going up the ladder or coming down a snake.

Figure 3: Live Sized Snakes and Ladders Board Designed for Values-Based Play

4.4 Evaluation

This section evaluates the appropriateness of the methodology applied for creating the physical artefact, the relevance of the physical game design elements, and the overall effectiveness of the game. This is in line with Hevner et al.'s (2004) design science research guidelines to include a rigorous evaluation of the artefact designed to determine its usability, quality and effectiveness; and that a design artifact is considered 'complete and effective' when it satisfies the requirements and constraints of the problem it was meant to solve. Our objective in this phase of the research, however, is not to create a complete and effective artefact, but one that serves as an iteration to guide the next iteration of artefact design and implementation. This is more closely aligned with principle 5 in Sein et al's (2011) stages and principles proposed for the ADR methodology. Given the multi-methodological approach to Insider Action Design Research, we adapt Hevner et al.'s (2004) Design Science evaluation guidelines to evaluate the physical artefact.

The physical artefact design, in this case, the live sized, values-based Snakes and Ladders game is underpinned by several conceptual, procedural artefacts and system artefacts. These are included in the evaluation. All the categories of Hevner et al.'s Design Evaluation Methods are applied to this research and adapted to fit the context (Hevner *et al.*, 2004).

Conceptual artefacts refer to the concepts, models and theories driving the game design. Here we first evaluate the appropriateness of the IAGDR methodology used. In this context, this is done via Observational, Experimental and Descriptive Methods (Hevner *et al.*, 2004). The adaptation of the methodology was appropriate for this context, with the pre-existing relationship between the researcher and the teachers involved in designing the values-based game. The methodology is seen as fit for the purpose of this research because it not only addresses a research problem outlined for design science, but also fulfils an organization's objective of creating an effective, engaging, and enjoyable values-based game for their 5 to 6 year-old students (Informed Argument). Then we evaluate the Values-based Transformative Games Design model via Observational, Experimental and Descriptive methods. We also evaluate the values (Schwartz and Bilsky, 1987)used in the artefact and the theory underpinning the choice of values (Bandura, 2001) via Observational, Analytical, Experimental and Descriptive evaluation methods.

Next, we evaluate the procedural artefacts i.e. the artefacts associated with the process of playing the game, as well as the post-game debrief process. The evaluation of this artefact is primarily via the Observational and Descriptive methods to assess the short term goal of reinforcing positive values in an engaging and enjoyable way, including post-game observations and feedback from teachers and players.

Finally we evaluate the actual artefact/system artefact, the live sized Snakes and Ladders board. This is evaluated via all five categories of the design evaluation methods – Observational, Analytical, Experimental, Testing and Descriptive (Hevner *et al.*, 2004). A team of 4 teachers, including the researcher designed the game, with 7 players. The game was evaluated, both via observing its implementation, and having in-depth discussions about the game from conception to post-implementation. This included an analysis of the usability, effectiveness, and appropriateness of the artefact for the intended outcome of reinforcing selected universal values in the players. Overall, the feedback on the physical game was positive – from the teachers that designed and observed. Table 1 summarises the design evaluation methods applied to evaluate the physical values-based game of Snakes and Ladders.

Table 1: Physical Values-Based Snakes and Ladders Game Design Evaluation

		Evaluation Method								
		Observational	Analytical		Experimental		Testing		Descriptive	
Evaluation Artefact		Field study	Static Analysis	Dynamic Analysis	Controlled environment	Simulation	Black box testing	White box testing	Informed Argument	Scenarios
Conceptual	Insider Action Game Design Research Methodology	x			x				x	

		Evaluation Method								
		Observational	Analytical		Experimental		Testing		Descriptive	
	Transformative Game Design Model	x			x	x			x	
	Universal values	x			x				x	x
	Social cognitive theory of games (Bandura, 2001) **[Concept of the game]**	x	x		x	x			x	
Procedural Artefacts	**Game process: Habit formation process**	x							x	
	Post-game debrief process	x							x	
System Artefacts	**Live sized Snakes and Ladders game**	x	x	x	x	x	x	x	x	x

5. Digitized artefact

In this section we discuss the design and implementation of a digitized artefact based on the experience of designing and implementing the physical artefact. This is discussed in terms of what we observed, theory building, the development of the digitized game, and its evaluation.

5.1 Observation

First, we reflect on the physical Snakes and Ladders values-based game compared to other physical values-based games for the young, and literature on values-based games for the young. We find that there are only a handful of games that are specifically values-based, and for children. The values-based version of the Snakes and Ladders game is not novel, yet not used commonly for this context today. Several articles surprisingly point to its roots for values education in ancient India, a fact none of the teachers were aware of prior to conceptualising this game. The live sized board was noted to be a novel and fun approach compared to the board game.

Other research projects studying values in games also included a physical/tangible game iteration prior to designing or suggesting a framework for digital values-based game design (Belman *et al.*, 2011; Flanagan and Nissenbaum, 2014; Spil and Bruinsma, 2016; Kheirandish and Rauterberg, 2018). Common modalities for physical values-based games are board games, including cards, or memory card games. When studied through the social cognitive theory lens and the Values-based Transformative Games Design Model, all these games are mostly focused on the “Educate” part of the model, and “Practice” where the game is played repeatedly, with the players gaining familiarity with the value scenarios in the game.

5.2 Theory Building

Following the evaluation of the game, two possible variations of the game are considered (applicable both to the physical artefact, or a digital version of the game). Firstly, the option to flip the game mechanism to include decision-making by the player. I.e., some boxes on the Snakes and Ladders board are marked to indicate a decision-making scenario. Based on the decision made by the player, either a Snake or a Ladder appears to demonstrate consequences of the different decisions. The player wins by getting through the board first but this time, it is not just a matter of chance i.e., landing on a Snake or Ladder, but rather, their decisions help them get through the board faster.

Another alternative is to have the scenarios on some of the boxes on the Snakes and Ladders board. The player is then required to guess whether the scenario calls for a Snake or a Ladder, and the selected option then appears. The player scores points for guessing this correctly, so the winner is not the player that gets through the board first, but the player that scores the maximum number of points.

These alternative mechanisms may be a more indicative way to demonstrate the impact and effectiveness of the game, as well as evaluate other aspects of the Values-based Transformative Games Design Model.

5.3 Game Design

The variations of the game also provide the potential to build a repository of values' scenarios to pick from. For instance, we picked Universal Values to demonstrate the implementation of the physical artefact in this section, but in a digital context, a player or game facilitator may choose values related to sustainability.

The other benefits of a digital version are to help reach more players globally. Having a digital version also provides the opportunity to include a link to the real world. Our digital and physical worlds are closely intertwined, helping us tap into the potential of digital games to transform in the real world.

An instantiation of a potential digital version of the values-based Snakes and Ladders game is as shown in Figure 4. The specific values in the game are good health and wellbeing in the young through healthy habits. This is a universally recognised value as part of the 17 UN sustainable development goals – sustainable goal 3.

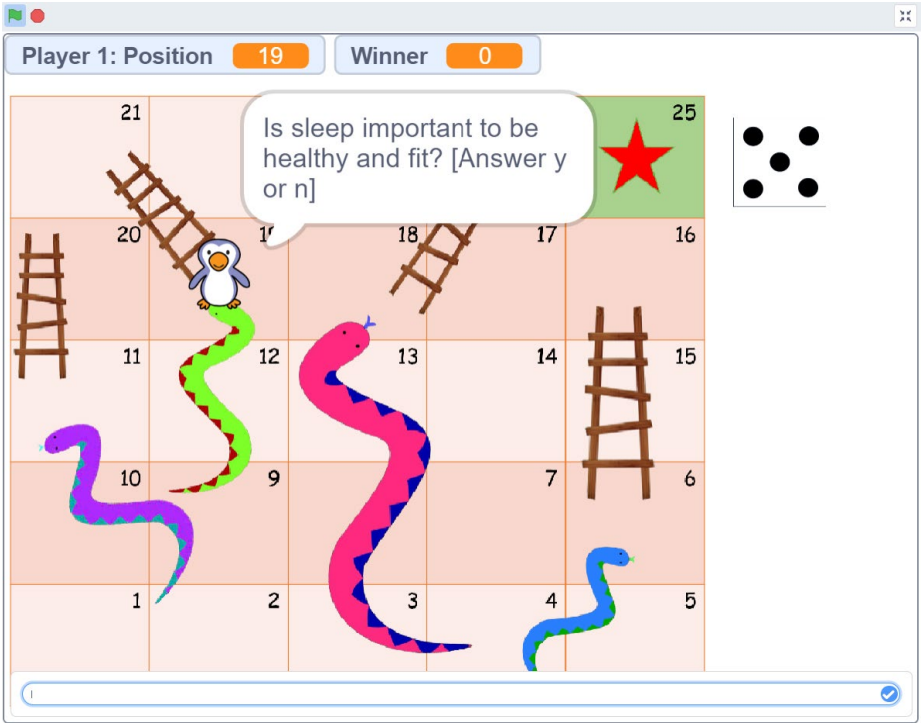

Figure 4: Digitized Values-Based Game of Snakes and Ladders

5.4 Evaluation

The digitized artefact was evaluated informally via observation of players navigating through the game. Some initial feedback included having a bigger snakes and ladders board, having the ability to customise player icons and colours, the possibility of having levels so players can advance from basic to more complex questions about the values involved, making the value being communicated more visible and explicit, and lastly, to have a dynamic question bank so players don't get bored with the same questions across the board.

6. Conclusion

This research discusses how games can be designed to go beyond being educational to transforming behaviour. This can be done via the design and implantation of values-based games because it is the fostering and changing of one's values that leads to transformation.

The aim of this research was to demonstrate the design and implementation of a values-based and customisable version of the popular board game, Snakes and Ladders via a Values-based Transformative Games Design Model. We created both a physical artefact, as well as a digitized artefact adapted from the Snakes and Ladders board game to demonstrate this.

We focused on values for related to good health and wellbeing in the young through healthy habits, a universally recognised value as part of the 17 UN sustainable development goals.

The Insider Action Game Design Research (adapted from Jrad, Ahmed and Sundaram, 2014) methodology was applied to create a physical artefact given the researcher's involvement in volunteer work in values-based education for the young. The experience, feedback and observations of designing and implementing the physical artefact was then used to guide the design and implementation of the digital artefact.

The key contributions from this research are the conceptual artefacts proposed such as the Values-based Transformative Games Design model and process of creating a physical artefact followed by a digital artefact, and the evaluation process. The findings of the research are of immediate benefit to those wishing to introduce a digitized version of a simple and popular board game to teach values to the young. The actual values-based questions used in the game are easy to adapt so the game has the potential to be extended to various other basic literacies, as well as different types of values such as sustainability and cultural values. Practitioners such as game designers can also apply the Values-based Transformative Games Design model for other types of games, both physical and digital. Last, but not least, researchers can further validate the conceptual artefacts, as well as enhance them through future research.

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Educational Story-Based Game for Capturing the Learner's Personality

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Abstract: In recent years with the help of digital games there is an increasing interest in creating Serious Games for learning through play. With the help of machine learning algorithms, an educational serious game can be used, not only to assist the learner in his/her studies, but also to extract insights about the learner's personality. In game-based learning we take into account that the student behaves differently according to his/her individual characteristics while learning by playing. The most used method to model the learner's personality is the self-report using questionnaires. The drawback of this approach is that the learner may not assess himself correctly or his/her answers' may be biased towards the more socially acceptable responses rather than being truthful. In this paper, we explore the idea of having an alternative method of learning a person's personality model and thus to better create interactive and engaging methods to assist learners in their studies. A story-based game with gamified learning elements was created for helping the learners study and evaluate their knowledge in the programming language C. The students learn by evaluating code snippets and depending on their response the game would give constructive feedback. At the same time students' in-game behavior is captured and thus their personality traits could be determined. For modeling the learner's personality we used the Five-Factor Model (OCEAN), a taxonomy of five personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism), each of which combines many personality characteristics. To evaluate the efficiency of the proposed serious game, we gathered data from 107 first year Computer Science students from the University of Macedonia. The students played the game and filled in the Big Five Inventory (BFI) questionnaire to capture their OCEAN traits. The BFI questionnaire was used as a ground truth. After the data gathering, we used machine learning techniques and also classification algorithms to create our model. The goodness of the model was assessed using different metrics and the results showed that it is effective to model both the extraversion and openness personality dimensions using serious games instead of questionnaires.

Keywords: Personality, Game-based learning, Gaming behaviors, Learning analytics, Data analysis

1. Introduction

The utilization of Serious Games (SGs) as an educational tool is a recent phenomenon, and its full potential is yet to be fully comprehended. In recent years there is an increasing focus on adding SGs to the education field. A lot of studies have compared the effectiveness of traditional teaching methods in comparison to an educational SG (Prensky, 2006). Results have demonstrated that educational SGs have a lot of advantages compared to traditional ones. The traditional environment has become boring and unmotivated. Especially a generation born with so much technology around (Barron, 2015).

In comparison educational SGs can be more appealing and encourage the learner to try to apply his knowledge. This gives the possibility for the learner to apply or simulate his knowledge, which can be hard to achieve in a classical environment. In a well-designed educational game environment, the learner can have fun while learning, making the process more enjoyable and less stressful (Schunk, Pintrich and Meece, 2008).

Although learning through gaming may be appealing, not all learners have the same likings. Several studies show that different personalities tend to prefer different learning styles, game genres and playing strategies (Pavalache-Ilie and Cocorada, 2014). The requirements to know each learner's personality have increased in order to better utilize the best-suited teaching model for them. The most used method for modeling the learner's personality is through self-report questionnaires. Using questionnaires has some limitations. The main limitation is that the learner may not answer the questions truthfully. The learner may choose the more socially acceptable answer or hide information if he believes he won't benefit from responding. Another important concern about self-reports is that the learner may not have the necessary self-awareness needed for the questions. Although a lot of these concerns and weaknesses can be reduced by using various techniques, it is clear that using multiple methods to capture the learner's personality is beneficial (Chen and Lin, 2017), (Judd and McClelland, 1998).

This study focuses on creating an educational SG with the ability to model the player's personality type. This can be achieved by capturing the players' game behavior. The design of the SG is focused on capturing the Extraversion and Openness personality traits as they are the most impactful dimensions towards a learning

system. The findings in this study can help the advance of using digital games with a serious intention. More specifically, to have an alternative method of learning a person's personality model as also to better create interactive and engaging methods to assist learners in their studies.

The rest of the paper is structured as follows: Next section presents the background and related work to the current study. In Section 3 the educational game is described and the conducted experiment to evaluate it is presented. Section 4 presents the obtained results from the data analysis. Finally, the conclusions and future directions are given in Section 5.

2. Background and Related Work

2.1 Personality

Personality is the enduring configuration of characteristics and behavior that comprises an individual's unique adjustment to life, including major traits, interests, drives, values, self-concept, abilities, and emotional patterns. Personality is generally viewed as a complex, dynamic integration or totality shaped by many forces, including hereditary and constitutional tendencies; physical maturation; early training; identification with significant individuals and groups; culturally conditioned values and roles; and critical experiences and relationships. Various theories explain the structure and development of personality in different ways, but all agree that personality helps determine behavior (APA, 2023).

In order to predict learners' personalities, various personality models have been proposed in the literature and one of the most used is the Five-Factor Model (FFM) also known as OCEAN (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) model (McCrae and John, 1992), (Franić et al, 2014). This model is one that is both compatible with the present view and consistent with everyday observation. The theory behind this model is that each person can be described by using five traits (Openness, Conscientiousness, Extroversion, Agreeableness, Neuroticism). Each person has a score in each dimension and through the scores someone can determine the tendencies of a person. For example, a person with a high extraversion score may be more outgoing and talkative and in comparison, a person with a low extraversion score may have more introvert habits like preferring to stay at home or being more reversed. To calculate a person's OCEAN score the most common method is through a self-report questionnaire. Each statement in the questionnaire targets one specific trait, the person rates in a Likert scale how much he/she relates with the statement. At the end of the questionnaire after adding the score of each statement the person's personality can be determined. There are some official questionnaires for the FFM. In this research we used the Big Five Inventory (BFI) questionnaire to model our players personalities (John, Donahue and Kentle, 1991) which has been used widely and is found reliable. It contains 44 questions and each question targets one trait of the OCEAN model.

2.2 Related Work

SGs are digital games that have as a primary purpose something different from entertainment. A SG is a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives (Zyda, 2005). For example the SG "Emeraude Escape" was created with the purpose to raise awareness about the importance of data and AI in our daily professional lives. Some other purposes can be art, education, scientific exploration, health care and so on. Of course, as the name implies it is a "game" so although the main purpose isn't entertainment it is still important for the final game to be enjoyable (GAIA, 2023).

Few works have been conducted which used digital games to model the learner's personality. In their study Denden et al. (2017) it was examined what systems and game elements are preferred based on the learners personality. Their study used the OCEAN model for the modeling of the personalities and it was focused only on the extraversion trait (low, balanced, high). The research modeled which game element is preferred or not by the extraversion trait. For example the badges were preferred by low, balanced and high extroversion. This wasn't the case for the leaderboard that was only appealing to the balanced and high extraversion trait.

Denden et al. (2018) proposed a framework for implicitly modeling the learners' personalities within a game-based learning environment using their gaming behaviors. The proposed framework is based on an online role-playing game for teaching the Computer Architecture subject and a learning analytics system. The learners by playing the game generated some game behaviors. In this study by using the BFI questionnaire and the LA system the learners' personality model could be made and evaluated. The efficiency of the proposed framework was evaluated with an experiment of 45 participants which focused on correctly modeling the

Extraversion and Openness traits. The proposed framework had a high level of accuracy with a good and a moderate agreement degree with the BFI.

Afroza et al (2021) developed a 3D digital game for the purpose of measuring some traits of the player's personality. The target of the study was the creation of a method faster and more enjoyable than the traditional questionnaires. The measured traits were based on the OCEAN model and were the Extraversion, Conscientiousness and Neuroticism traits. In their study they validated the proposed game as a personality measurement tool conducting a correlation analysis between the results from the game with those of the BFI. The results showed a moderate correlation on the Neuroticism trait and small correlation on the Extraversion and Conscientiousness.

3. Methodology

3.1 Design of the Game

The game has two main purposes: to assist students in their learning activities and also through their in-game behavior to determine their personality traits. Finally, as a game it should be entertaining. To cover all these targets a story-based game was designed.

3.1.1 Flow of the game

In the game the student plays as a fresh trainee in a small company. The student has to accomplish his "work duties" in the morning. These duties are to review some submitted code snippets from "other" applicants and accept or reject them depending if the snippet is answering a given exercise description. The acceptance or the rejection of the code snippet can be applied by pressing the relevant "accept" or "reject" button. After the learner's evaluation of the code an immediate feedback would occur. The feedback first would inform the player if he/she assessed the code snippet correctly. After the code's assessment an additional text would be provided explaining the answer's main concept. The code snippets are written in the programming language C. After finishing the "work duties'' the student can leave the office and go to the "day's event". Every day a different event occurs. At the event the student meets his/her work colleagues and interacts with them. There is a main story that progresses through the days with a final choice at the end of day 8.

The player each day interacts with their work colleagues. Through their conversations the game gathers data about the player's preferences and opinions. The interactions usually are social events like a welcome party, coffee, meetings in the office or going to an art gallery. In the middle of the game there is a special interaction where the company's director goes to the player's office and informs him/her that the company might need to lay off one of their working staff and the player's opinion might be useful. On the last day of the game the director goes to the player's office once more and asks him/her which work colleague the player suggests to lay off and why. The player can give a reason based on the selected colleague's character or declare that the choice was at random.

3.1.2 Design choices

When a player plays a story based game he/she is bound to have a "relationship" with the game's character or avatar (Bowman & Schrier, 2018). There are multiple dynamics and relationships the player can have but this research focused on creating the feeling that the player is playing as himself.

The game elements implemented for this are the first person view, the inability of the player to see his/her body in order to avoid "conflicts" between the avatar's virtual body and the player's real one. Although the game's scenario isn't a common one it is realistic and the conversations between the player and the Non-playable characters (NPCs) are responsive, meaning that the NPCs would say something based on the player's answer making them feel more alive.

Some additional game elements were implemented in order to make the study of the programming language C more appealing and interesting for the player. First there is a score that the player can see on his/her screen. The score is directly influenced by how well the player does his/her "work duties" (Figure 1). If for example the player rejects a correct code snippet his score will decrease. This game element gives a sense of reward in the player's actions and choices. It also emphasizes the impact of the player's choices.

Figure 1: Player's view and score

Additionally, after the player's evaluation of the code snippet there is an immediate feedback. If the player correctly evaluates the code snippet then a green tick will appear indicating that he did a good job. On the contrary if the player made a wrong evaluation then a red "X" would appear. A small text below explains why the principle regarding the correct choice. In this way the player could "fill" his/her learning gaps and quickly realize what he/she knows. The game's feedback is written around the question's concept. For example, in the (Figure 2) the question's concept is that if all the parts of an equation are integers then the result will also be an integer. So "11/2 = 5" and not "5.5" as the "applicant" answered. To avoid having multiple concepts in a single question the code snippets are small in size and don't involve any additional learning concepts other than the targeted one. Furthermore, except for their small size the code snippets contain only logical errors. With this approach the player won't get lost in trying to read a big program or get something wrong just because the code is missing a semicolon (Figure 2). The code snippets the player had to assess address a different learning concept each day. In the first days the code and the questions are focused on more basic concepts of the programming language C and as the game is progressing so is the difficulty of the questions. The code exercises are checking the abilities of the students regarding the flow of actions in C, the use of if-else statements especially how not to mix subsets of conditional statements, loops, the ability of the students to read and understand the code's functionality and finally some general knowledge in C.

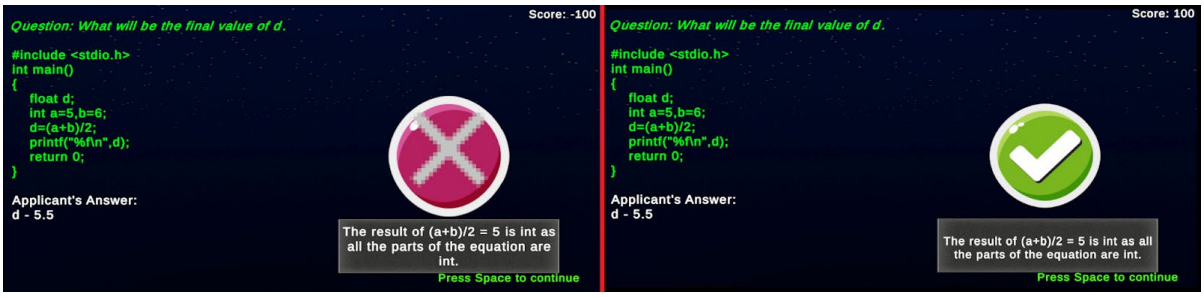

Figure 2: Wrong and correct assessment of the code snippet

For gathering data for the learner's personality an interactive story was created. In the story there were conversations between the NPCs and the learner. The conversations had both questions from the BFI and findings from other researchers regarding the tendencies of the openness and extraversion trait of the OCEAN model (Choungourian 1967), (Watson and Clark 1997).

More specific for the openness trait the conversations were targeting to capture the learner's will to try new experiences, how much risk the learner is willing to take, his/hers views about art, his/hers color preferences and his/hers tendencies regarding the way he/she interacts with the NPCs. For the extraversion trait the conversations were targeted to capture the learner's enthusiasm for communication with the NPCs, his/hers color preference, his/hers will to take risks as also the tendencies regarding answering NPCs. The available responses in the conversations were created with having in mind the targeted trait of the player's answer as also the possible answers a person with each characteristic (low, balanced, high) would give (Figure 3).

The choices from the conversations between the player and the NPCs were used for modeling the learner's personality. Each conversation was saved in an array with categorical values. For example the array [2,1,4] means that the learner selected the second choice in the dialogue then the first and finally the forth one. As

the game was designed to be responsive, interactive and give the feeling of life-like NPCs there were multiple conversation paths. For example, on one occasion the NPC could ask a question, depending on the player's answer a different conversation path could be followed.

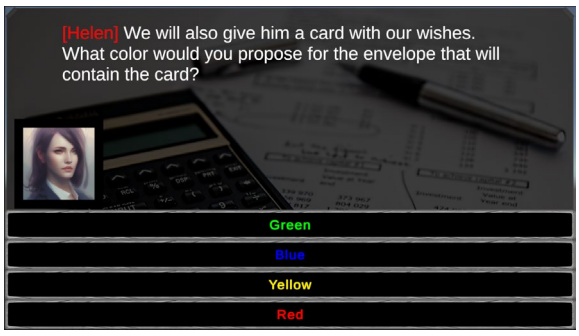

Figure 3: NPC asking player to select color (extroverts tend to prefer warm colors)

3.2 Participants

This research took place in a Computer Science department. The participants were 107 students, 72 male and 35 female students. The students were learning the programming language C (first year curriculum in the university) and they also got a small bonus for participating in the case study. The students first played the game and then they had to fill in the BFI questionnaire in their own time on the same day.

3.3 Procedure

The learners start by playing the game. The game needed around 40 minutes for its compilation. Before the start of the game the learners were introduced to the game's controls and story. At the beginning of the game there was a mini tutorial area to teach the learner's the controls, the user interface and the flow. The learners played the game on their own computer. After the completion of the game the learners had to fill in the BFI questionnaire. A deadline for this task was given not later than the end of the day.

3.4 Data Analysis

For the data analysis the answers to the questionnaire were used as the ground truth. As the game's design was targeting the capture of the Openness and Extraversion trait the given BFI questionnaire had only the questions related for these two traits. More specifically 8 questions were for the extraversion and 10 for the openness trait. As for the trait description there are three distinct categories. Low, balanced and high. To determine each category the mean of the learner's score was used. The mean can be between 1 and 5. The mean-scores in the range 1 to 2.4 were labeled as low, 2.5 to 3.4 as balanced and 3.5 to 5 as high.

First it was checked if there was sufficient data in each category. For the extraversion trait the distribution was 18 learners had low extraversion score, 50 had balanced and 39 had high. For the openness trait the distribution was 2 learners had low extraversion score, 46 had balanced and 59 had high. Because of the low number of learners with low openness scores the prediction of low openness was excluded. After further searching both of the 2 learners with low openness score had a mean score of 2.4 which is the borderline for balanced score. For this reason it was decided to label them as balanced and keep their metrics.

The data gathered from the game were used to predict the results from the questionnaire. As it is already mentioned in the Design choices subsection, the NPC could ask a question and depending on the question the player would answer differently following a different conversation root. Although these conversation paths are small and quickly "reconnected" to the main conversation path they still generate some different arrays. To make the data more homogeneous only the main conversation path was kept. It is important to note here that the choice to drift from the main conversation path was part of the main conversation root.

The player's score as also the success from each player in his/hers in-game "work duties" didn't taken into account for the analysis. We didn't include these two metrics in the analysis as the metrics mostly represent the learner's knowledge for the programming language C and not his personality. To avoid overpopulating the training data with low relevancy data we excluded these metrics.

For the data analysis three algorithms were used: KNN, decision trees and Naive Bayes. The algorithms were trained with various techniques and compared the results. All the models showed better results using firstly PCA to reduce the data dimensions. Also, the models were trained with different training sets (excluding

dialogues or conversations that targeted a different trait of the one we were modeling). Finally, after finding a good model different seeds were tested to find the optimal result. The criteria for choosing a model were through the metrics of f1-score and ROC/AUC score.

4. Results

The results show good scores in both the accuracy metric as also the AUC/ROC score. A different algorithm and seed were best suited for each trait. For the extrovert trait the most suited algorithm was the decision trees. The model can determine extrovert characteristics (low, balanced, high) with accuracy 72% from the game data. Also, the f1-score of 0.736 and AUC/ROC of 0.741 score shows that the model is reliable (Table1). To further determine the agreement degree between the model and the BFI questionnaire the Cohen's kappa coefficient was calculated. Cohen (1960) suggested the kappa result be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement. The decision trees had a score of kappa = 0.54.

For the Openness trait the algorithms had better results. The most suited algorithm was the Naïve Bayes. The model had accuracy of 81% to correctly determine the learner's openness trait (balanced, high). Also, the f1-score of 0.811 and the AUC/ROC score of 0.75 support the model's results (Table 2). Lastly the Cohen kappa score of the algorithm was 0.636 indicating a good agreement with the BFI questionnaire.

Table 1: Extrovert results

Extrovert	Accuracy	F1-score	Kappa	AUC/ROC
Naïve Bayes	0.5454	0.566	0.276	0.627
Decision Trees	0.727	0.736	0.541	0.744
KNN	0.59	0.578	0.292	0.559

Table 2: Openness results

Openness	Accuracy	F1-score	Kappa	AUC/ROC
Naïve Bayes	0.818	0.811	0.636	0.75
Decision Trees	0.545	0.541	0.09	0.998
KNN	0.636	0.633	0.272	0.617

5. Conclusion, Limitations and Future Directions

In this study we developed an educational SG with the purposes of assisting the learner in his studies and additionally from the learner's in-game behavior to model his/hers personality model through the OCEAN theory.

The results obtained by analysing the learners' in game behavior showed a good and a moderate agreement between the study's model of the extraversion and openness trait and the BFI questionnaire. These findings support the hypothesis that the learner's personality can be determined through his/her choices in the game. More specifically the Decision tree algorithm performed better than the other algorithms at determining the Extraversion trait and the Naïve Bayes had better results for determining the openness trait.

In comparison with the related work this study had some differences. The most similar study to this one was the creation of the CAG framework by Denden et al. (2018). In comparison in this study the number of participants was higher and as not a whole framework was created but a targeted game the accuracy of the algorithms were higher. In addition, this study used multiple algorithms to model the learners' personality instead of one.

Although it wasn't inside the scope of this research the results of students' performance during their "work duties" could be used to give some further insight to the professor regarding the students' general level and understanding. For example, if the students show some difficulties on correctly assessing some if-else statements then the professor can further explore if this was due to unclear constructed questions in the game or if the students have some difficulties understanding this concept.

Even though the results are promising there were some limitations on this study. The number of participants of this experiment (107 in total) is not high enough and they were all from the same University. Although there

was a relationship between the learner's choices in the dialogues and his/her personality the dialogues weren't constructed with the help of an expert in psychology meaning not the full potential of the dialogue choices were used.

Some suggestions for future work based on this research: Modeling the remaining personality dimensions through the game data. Use a third personality modeling method in addition to BFI for further comparing the results because as mentioned the self-report questionnaire may be the most used method but it is not perfect. Use adaptive elements in the game based on the learner's personality and study the learner's response to them. For example learner's with high extraversion prefer hot colors over cold. This can be utilized for adding more hot color themes in the game's UI. Finally further research can be done on finding the optimal way for grouping students regarding their personality model.

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Fostering Employability Skills for Engineers With Serious Games: A Gamified GBL Concept

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Abstract: The world is becoming increasingly complex, and as a result, the demand for individuals with strong employability skills is growing rapidly. It is essential for engineering education to adapt to this reality and provide opportunities for students to develop critical thinking, problem-solving, communication, teamwork, adaptability, and leadership skills. By doing so, engineering graduates will be well-equipped to navigate the complex challenges of the modern world and make meaningful contributions to society. Engineering education needs to adapt to this reality by incorporating more opportunities for students to develop their employability skills. This can be done through a variety of methods, such as experience- or project-based learning, internships, co-op programs, and industry partnerships. Game-based learning offers an engaging and immersive experience that can promote the development of these skills in a fun and interactive way. Within the Game-based learning approach implemented in our lecture the students play two subsequent game modules in which they first plan and build a factory building together and then put it into operation in the second part. The players are confronted with problems and situations that can only be overcome through communication and cooperation. This paper presents the self-developed online platform that uses gamification aspects such as micro-achievements for each student to represent the progress with the learning materials as well as within the gaming parts. The platform aims to provide students with an engaging and interactive way of learning, while also assessing their performance through collected data.

Keywords: Game-based learning, Engineering education, Employability skills, Gamification, Serious games

1. Introduction

Engineers are facing the demand for a holistic comprehension of the digital transformation, encompassing intricate contexts such as companies, technologies, and markets. They need to integrate technical and methodological competencies rooted in STEM fundamentals with specialized skills from disciplines like mechanical engineering, computer science, and more. Additionally, cross-functional competencies, often referred to as future skills, are crucial for engineers to navigate this evolving landscape successfully. (VDI 2019; VDMA 2019; Stifterverband 2018, 2021). In order to facilitate this, universities are urged to adopt a perspective of being open learning systems. This entails fostering co-creation processes among all stakeholders within the university and establishing a conducive environment for personalized study designs, intelligent systems-based personalized learning, and enhanced integration of research and teaching. Embracing the concept of universities as digital learning ecosystems has implications for shaping graduate profiles, curricula, learning environments, and assessment methods. In this regard, digital and hybrid teaching and learning formats hold great potential for enabling co-creation processes within the framework of open learning ecosystems.

The Faculty of Process Engineering, Energy, and Mechanical Systems at TH Köln/University of Applied Sciences welcomes approximately 800 first-year students every winter semester. The engineering education at TH Köln emphasizes competence and project-based learning, which places significant emphasis on students' methodological skills (e.g., project management) and their ability to work effectively in interdisciplinary teams. These skills need to be nurtured right from the beginning of their studies. However, the expectations of first-year students regarding the content of their engineering studies may not align with the compulsory modules focused on methodological and interdisciplinary competencies, such as the module "work techniques and project organization" worth 5 ECTS. To address these challenges, the FutureING mixed-reality game was specifically developed (Richert et al. 2019). This paper presents the self-developed online platform that uses gamification aspects such as micro-achievements for each student to represent the progress with the learning materials as well as within the gaming parts. The platform aims to provide students with an engaging and interactive way of learning, while also assessing their performance through collected data at a later point.

2. Game Based Learning and Online Laboratories

The concept of FutureING aligns with current research discussions on game-based learning and online laboratories, which are essential components of engineering education. Laboratories serve as platforms for students to apply theoretical knowledge in practical settings and acquire hands-on experience (Bernhard, 2010).

These laboratory experiences encompass both theoretical and conceptual knowledge and provide opportunities to develop procedural and technical skills. Additionally, laboratories are well-suited for fostering employability skills, which are highly valued in the engineering field (VDI 2019). Practical experience also holds a crucial place in engineering education and is integrated into the curricula of many study programs. With the advancement of digital technologies, students now have the opportunity to engage in laboratory activities remotely, offering increased availability and flexibility in terms of time and space. This digital transformation enables students to access laboratory situations through virtual environments, thereby enhancing their learning experiences.

By embracing the potential of digital technologies and integrating them into the FutureING concept, students can engage in laboratory-like experiences from anywhere, at any time. Remote access to laboratory settings not only expands the reach of practical education but also provides students with the flexibility to engage with the content according to their own schedules. This accessibility opens up new possibilities for learning and empowers students to explore engineering concepts beyond the confines of traditional physical laboratories. Serious Games, which simulate engineering scenarios and involve collaborative gameplay among multiple students, can be regarded as a form of laboratory experience. Research has consistently demonstrated the numerous beneficial outcomes associated with game-based learning. Petko (2008) outlines several didactic potentials of digital games in education, including teaching strategic problem solving, facilitating situated learning, promoting social learning, motivating learning processes, illustrating complex interrelationships, and enhancing comprehension and dexterity skills. Among these educational possibilities, two key aspects are particularly significant for online labs, especially in the context of FutureING: the facilitation of social learning and the enhancement of motivation in the learning process through situated learning. In general, games that replicate authentic work environments can act as virtual laboratories for students to apply and assess their abilities and knowledge. By utilizing a gaming system, students are provided with a safe space for making mistakes, thus encouraging experimentation. Consequently, students can explore various approaches and assume different team roles while working on the same task.

Furthermore, games, with their diverse reward and control systems, are particularly suitable for project-oriented, problem-based, and experiential learning. They provide opportunities to train application knowledge in new situations. Virtual worlds, in particular, offer spaces that allow for the development of "digital" competencies, such as creativity. These worlds create varied and challenging work scenarios for students, engage them in real and exciting tasks, and foster a climate that promotes reflection and personal growth. Research indicates that game-based learning contributes to the development of competencies due to its motivational conditions, appealing to the instinct for play, recognition, competitive thinking, and ambition (Young et al. 2012). These approaches align well with a constructivist learning culture, where learners are active participants in the learning process and learning is seen as a social, emotional, and situated experience (Siebert et al. 2005). Consequently, game-based learning is gaining increasing importance in university teaching, imposing requirements on digital didactics in engineering education. The goal is to design "magic circles" (Huizinga 2017) where a safe environment for experimentation is created, failures are positively perceived, and motivation is encouraged. Simultaneously, these approaches should accommodate the heterogeneity of students in terms of their prior knowledge and experiences and address the diverse levels of knowledge through reflection.

3. Current Status

FutureING aims to create a collaborative mixed-reality learning environment within which a serious game is developed. This game transforms the "work techniques and project organization" module (ATPO) into an immersive and competency-based learning experience, effectively connecting interdisciplinary and specialized content. By employing action-oriented teaching methods from the realm of game-based learning, abstract knowledge is linked to practical personal experiences. The existing successful approach of combining traditional courses with elements of business games is further enhanced in FutureING. This digital, game-based concept integrates various components, including classic e-learning, immersive augmented and virtual reality elements, as well as face-to-face interactions (presence elements), resulting in a comprehensive learning experience. The concept of virtual studios (Broadfoot und Bennett 2003), adapted from the field of engineering disciplines, allows for the simultaneous development of technical and methodological skills. From the very first semester of their engineering studies, students engage in the digital transformation within a production company through the FutureING program. Acting as an engineering office, they are tasked with designing and optimizing production processes for a robotics manufacturer. Within the game's framework, students collaborate within fictitious engineering offices. In the following sections, the different FutureING elements are described.

3.1 FutureING AR-Game

The initial game in the FutureING series, known as the FutureING AR Game, has been fully developed and is now available on both iOS and Android platforms. The AR app has reached a stable release status, encompassing all the planned features. Designed as an online multiplayer game, the AR app allows every student to participate from the comfort of their homes using their smart devices. Distribution of the app was facilitated through the respective app marketplaces for Apple and Android devices. To ensure a seamless multiplayer experience, students were connected to the same game session using unique group codes. As the name suggests, the FutureING AR App incorporates augmented reality (AR) technology, creating an immersive environment by projecting a virtual factory hall onto a table and providing players with an overhead view. Within the app, students are tasked with strategically planning multiple assembly halls across a series of levels, aiming to achieve predetermined production goals. Once students believe they have found a solution that meets the requirements of a level in the game, they have the opportunity to purchase assembly cells and autonomous transportation systems. Careful selection of the assembly cells is crucial, as machines with similar qualities may perform differently based on the quantity of products that need to be produced. The same applies to the autonomous transportation systems, with some excelling in long-range transportation and others in short-range transportation. In the game, students must select two out of three optimization options: budget efficiency, time efficiency, and production reliability. The game aims to present solutions with individual strengths and weaknesses that are all valid, as there are multiple paths to achieve the goal. This variety of solution spaces encourages students to engage in discussions about which solution to pursue. Once students have placed all the necessary components within the production hall within their budget, they can start simulating the production process. During the simulation, they receive immediate feedback on whether their solution is able to meet the production goal. After the simulation, students are awarded star ratings and can choose to replay the level or progress to the next one. Beginning with a tutorial and gradually progressing to more challenging levels, students will have the opportunity to test and refine their planning skills throughout the game. The final level will present the most complex challenge.

3.2 FutureING Desktop-Game

In the subsequent game component, the FutureING desktop game, students immerse themselves in the operation of their planned production hall through the FutureING Desktop game. They assume responsibility for the initial production operations, facing various challenges and malfunctions that occur randomly. For example, they may encounter an installation within the production facility that has malfunctioned and needs to be examined for errors and restarted. The entire team is present on the production floor, with one group taking charge of the control room. This group has access to statistics and problem areas displayed on dashboards and can consult operating manuals. The other group remains on the shop floor, equipped with virtual tools and sensors. Their task is to collaboratively address technical problems by conducting research, analysis, and teamwork in a dynamic and turbulent production environment.

The FutureING Desktop Game consists of two phases, which can be played by the students in any amount of sessions. The game starts with a tutorial, in which the players learn the basics of the game in a failure-safe space. It is followed by Phase 1: In it, the players need to set-up the assembly hall using the knowledge they had gained in the tutorial. Here, the focal point lies on cooperation and communication, as many set-up tasks require inputs from several players to be solved or are puzzles that are implemented on the principle of asymmetric distribution of information. The students need to set-up the production hall in a tight, pre-defined time-frame.

In Phase 2 the assembly hall starts its production. However, errors in the machinery need to be fixed by the players to secure the group outcome. As a result, Phase 2, while having tasks of a similar manner like Phase 1, it creates a higher challenge for the students, as it also requires stress-resilience and flexibility and more communication and short-term planning.

3.3 FutureING TrainING Center

The current TrainING Center (1.0) serves as a knowledge resource and contains video lectures (such as classic and agile project management, scientific work, teamwork and team development, etc.). In addition, it contains the download links to both games. In its current state, it is used infrequently by the students. The aim of the developments described in this paper is to raise engagement of the students with the platform and thereby improving the learning outcomes and the amount of research data gathered through the competencies self-assessments and evaluations. In a next step, it is planned to assess student's performance based on data collected throughout the games and platform. The planned concept is described in section 3.

3.4 Effectiveness of FutureING

The module itself as well as the gaming components have been positively evaluated by students throughout the semesters. In addition to that, self-assessment of employability skills competencies was carried out three times throughout the semester. The first time (CSA1) before the games are played, the second time (CSA2) after the first game has been played and the third assessment when both games have been played. Figure 1 illustrates a consistent improvement in all skills assessed.

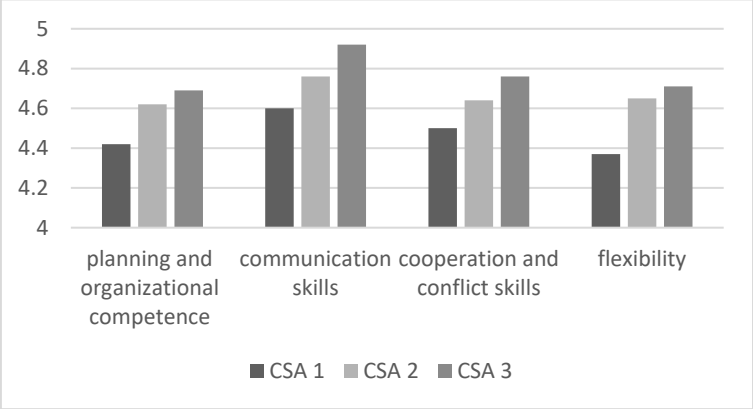

Figure 1: Results of the Competencies Self-assessment (CSA) throughout the Semester (N= 267)

The findings indicate a notable improvement in the assessed competencies throughout the semester. Students rate their competencies higher in all four areas after participating in both the AR game and the Desktop game. The observed growth suggests that students are effectively developing and acquiring the necessary competencies through the FutureING game. The data further suggests that the design of the two game components aligns with the targeted competencies outlined in the learning outcome. Based on the integration of the various teaching components, it can be concluded that the interconnected mixed-reality elements have a positive impact on the development of "future skills" competencies. Traditional soft skills, including planning and organizational abilities, communication skills, collaboration and conflict management, as well as adaptability, serve as valuable assets for handling complexity. These skills are effectively trained through the presented mixed-reality approach that combines them. As a result, we can confidently affirm that the overall FutureING concept, along with its components, proves to be highly effective in achieving the desired learning outcomes, successfully addressing our initial research question.

4. Improved TrainING Center

The TrainING Center 2.0 serves as a gamified platform for self-assessment and learning within the FutureING learning system. It operates both as an independent channel for students to engage in learning and self-assessment and as a subsidiary channel for the FutureING AR Game and the FutureING Desktop Game. In its subsidiary role, the TrainING Center connects the FutureING Games by establishing a shared account for data transfer between the TrainING Center and the FutureING games. Through their TrainING account, students can personalize an avatar. Inspired by role-playing games, the avatar possesses a set of skills that players can allocate their experience points to enhance. At the beginning of the TrainING experience, players receive a starting set of skill points based on a self-evaluation questionnaire. As they progress and perform in the FutureING games, they earn experience points that can be utilized to improve their avatar's skills. These enhanced skills grant players bonuses that prove beneficial in the FutureING games, motivating them to assume specific roles. For example, the "Purchasing Expert" skill reduces purchase prices in the games by 0.5% at level 1. Players can invest experience points to increase the skill level, with each level providing an additional 0.5% reduction in prices. Additionally, players can position their characters within the game worlds to oversee an Assembly Cell and enhance its capabilities. For instance, the "Quality Assurance Overseer" skill reduces the error rate of the assigned Assembly Cell by 5%. These example skills enable players to engage in roles during the games' planning process. For instance, a player with the "Purchasing Expert" skill might be responsible for acquiring equipment for the team, while a player with the "Quality Assurance Overseer" skill closely manages the Assembly Cells, further decreasing the error rate. However, players are encouraged to explore different roles within the team by reallocating their skills and reinvesting experience points within the TrainING Center.

The TrainING Center is designed as a website accessible either independently or from within the FutureING Games. It serves as an intermediary space between the levels of the AR Game and the phases of the Desktop Game. This creates a dynamic interplay between the intrinsic motivation derived from the engaging game mechanics of the games and the extrinsic motivation provided by the TrainING Center. The TrainING Center offers external motivation through a team-based leaderboard that tracks players' earnings in both games. To succeed in the games and improve their leaderboard position, players need to enhance their avatar skills. This incentivizes players to revisit earlier levels in the AR Game after levelling up their skills to achieve better results. Additionally, the games incorporate elements from free-to-play (f2p) games to encourage players to invest additional effort. Instead of real currency or advertisements, players can enhance their in-game performance by participating in quizzes available in the TrainING Center. These quizzes offer rewards ranging from cosmetic items and additional experience points to powerful one-time use abilities. The incorporation of f2p elements includes escalating difficulty curves that make it challenging to achieve perfect results without utilizing quizzes, as well as avatar customization options and the overall competitive nature of the TrainING Center.

In addition to that, player actions are logged and accumulated. The logs are then planned to be used to assess the players performance in the aforementioned future skills the game is trying to foster. As of now, using the logfiles from the previous semesters in combination with the exam results, the process of identifying key performance indicators for the given learning goals is underway. In the coming semester, using the TrainING center will become mandatory, and therefore much more data will be collected to enhance the logging.

5. Conclusion/Outlook

The TrainING Center as a gamified web platform aimed at motivating students to engage with lecture contents and the two serious games, seems to hold significant potential. To ensure its effectiveness and ongoing development, a comprehensive evaluation framework coupled with future developments is essential. This section outlines a scientific outlook on evaluating the TrainING Center and presents strategies for further development.

A multifaceted evaluation approach is crucial to assess the TrainING Center's impact and determine its efficacy in motivating students. Quantitative measures, such as surveys and questionnaires, can gather data on students' perceptions of motivation, engagement, and satisfaction with the platform. Additionally, analytics tools integrated into the TrainING Center can provide valuable insights into usage patterns, performance metrics, and learning behaviours, enabling a data-driven evaluation. The TrainING Center's ability to facilitate effective learning outcomes is a key aspect to evaluate. Pre- and post-intervention assessments can gauge knowledge acquisition, retention, and skill development. Traditional measures such as quizzes and exams can assess content mastery, while project-based assignments and real-world simulations can evaluate the application of knowledge and problem-solving abilities. Rubrics and scoring criteria specific to the TrainING Center's activities can be developed to provide a comprehensive assessment. To further enhance the TrainING Center's efficacy, student feedback is invaluable. Conducting user surveys, focus groups, and interviews can gather insights into students' experiences, preferences, and suggestions for improvement. This feedback should inform an iterative design process, allowing for continuous enhancements to the platform's features, user interface, and gamification elements. Regular updates and refinements should be implemented based on user feedback, ensuring the TrainING Center remains relevant and engaging. Gamification techniques such as leaderboards, badges, challenges, and rewards should be strategically implemented to foster motivation, engagement, and healthy competition among students. Exploring the integration of additional motivational elements, such as personalized avatars, interactive narratives, and social interaction features, can further enhance the TrainING Center's appeal and effectiveness.

Through a robust evaluation framework, iterative design, and ongoing development, the TrainING Center can fulfil its purpose of motivating students to engage with lecture contents and the two serious games. By employing diverse evaluation methods, incorporating students' feedback, enhancing gamification elements the TrainING Center aims to evolve into an effective and engaging platform that optimizes students' learning experiences and outcomes. The iterative nature of the development process will ensure that the TrainING Center remains adaptable and responsive to the ever-changing needs of students and the evolving landscape of educational technology.

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Utilizing Outdoor Quiz Games in Secondary School: Teachers' Perceptions of Usefulness

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Abstract: Outdoor play is a natural way for children of all ages to do physical activity. The advantages of being outdoor in an educational setting have been elaborated. For instance, the social constellations may change when outdoors as the social structures defined in the classroom setting no longer apply as the pupils may display different skillsets outdoors as to indoors. Using games for learning purposes have been employed for several decades. As far back as in 1904, the Landlord's Game was used to teach people about real estate and taxation. Since then games have mostly been developed for leisure purposes, but some also for educational purposes. In this paper, we elaborate on the use of a Norwegian developed quiz game called 'ZippyGO'. Most of the research on ZippyGO have been focusing on students' perceptions of the use of this quiz game. In this paper, however, we focus on the teachers' perceptions and use of an outdoor quiz game for educational purposes. In this particular case, four teachers have collaborated on developing questions for the quizzing. We conducted mixed method ways of collecting data, surveys and semi-structured interviews. Our investigations have focused mainly on how the teachers perceive working on developing adequate questions for the quiz and how they perceive pupils may react to using the quiz game. We have also challenged the teachers on their perceptions of games for learning purposes in general and about being outdoor during class.

Keywords: Educational game, Outdoor gaming, Quiz game, Teachers' perceptions

1. Introduction

The potential of learning from games have been explored for decades (Gee, 2007; Pivec and Kearney, 2007). There have been games for several different areas and disciplines such as history (Squire, 2005; Zin and Yue, 2009; McCall, 2016) and languages (Hubbard, 1991; Godwin-Jones, 2014; Klimova and Kacet, 2017). Games have even been taught to train for warfare (Vold and McCallum, 2009).

Generally, games have been developed and then put to use in, for example, a classroom. Some have been developed especially for bespoke purposes (such as games for warfare (Vold and McCallum, 2009)) or it has been commercial off the shelf (COTS) games, such as for example Sid Meyers Civilization games (Watson, Mong and Harris, 2011).

In this paper, we are presenting a game originally developed as an orienteering games-based application (app) with added functionality. The game is thus played outdoors.

1.1 The Game ZippyGO

The game ZippyGO is a downloadable app that works on both the android and IOS platforms. The app is developed by Ida Vår Kierulf Meyer at Konkylie Data As, Norway (www.konkyliedata.no). When downloading the app, you will get access to the "routes" made available to you. The app can either be used as a geo-referenced map with *controls*, or it can be used as a quiz-game. If it is used as a quiz-game, the quiz will appear on the screen of the device when being within a certain range of the geo-referenced point *(control)* marked on the map. The app will then allow you to answer the quiz right away or save it for later. The answers and e-mail address are saved on a safe server in Norway. When the period of the game is over, the data are erased.

The app is set up to allow, for example, teachers (or others) to develop a quiz-game with geo-referenced points. In this particular study, one of the researchers has access to developing a quiz-game and invited the teachers to come up with questions and answers for the quizzes. The questions were sent to the researcher and the researcher then added the quizzes to the quiz-game. Playing the quiz-game was part of the programme for an outdoor day during the pupils' semester. During the outdoor day the teachers are to do activities together with the pupils and during this particular day late in the spring semester, one of the planned activities was for the pupils to play ZippyGo.

Figure 1: Screenshot of the admin website of ZippyGO showing the map of the area

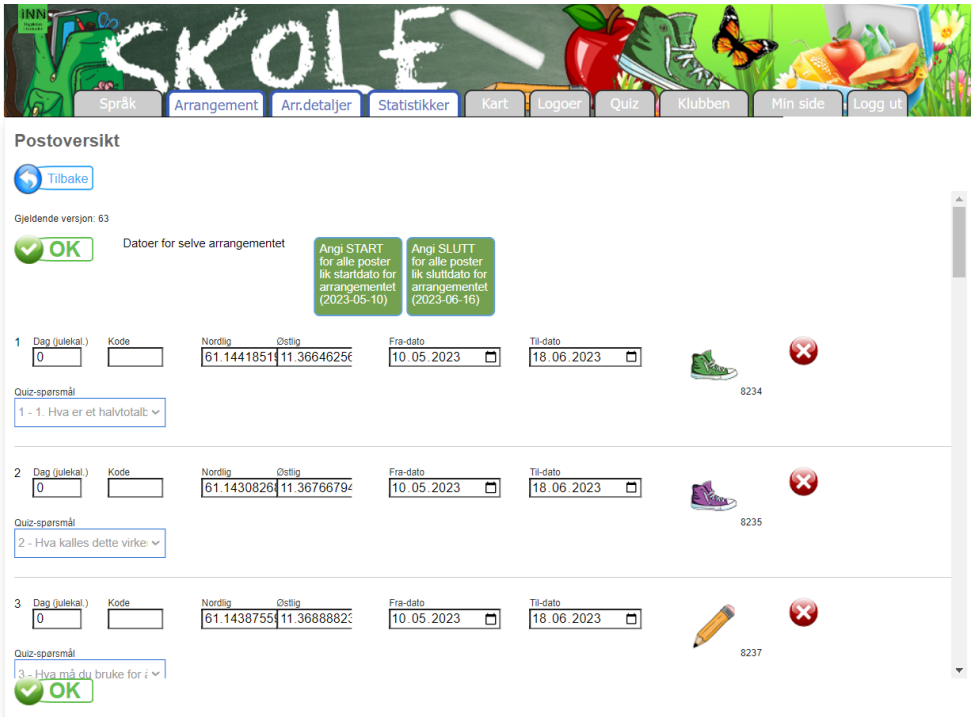

Figure 2: Screenshot from the admin website where the quizzes are added

The teachers' involvement was important in order to secure that the quiz-questions were within the scope of their learning objectives. The teachers of the different subject would have the best overview of the different subjects and their curriculum could thus focus the questions and answers within the frames of what they had been teaching. Since, this was a day for all of pupils on this particular level (level 9), we asked the teachers to collaborate and cooperate on developing the questions for the quizzing as we would also like to see if they could find any common use of the quiz-game after this study.

The pupils who were to utilize the game were pupils at the Åmot secondary school in the municipality of Åmot in the Inland County, Norway. The pupils are at level 9 in the Norwegian system (approximately between 14 and 15 years of age).

To each *control (*the geo-referenced point in the map), a quiz was assigned. The quizzes were developed by the teachers that volunteered for the project which taught the following topics: Norwegian (language), Science, Maths, English (foreign language) and Social Science. An example of a Science question for the quiz was: "what is the energy source called that comes from the centre of the earth? A: a) Geothermic energy, b) Bio-energy, c)

Solar energy (the correct answer was a) Geothermic energy)". The pupils were to solve the quizzes in groups of 3 to 5. Since this paper is focused on the role and perceptions of the teachers, our research question is:

What influences teachers' perception of the usefulness of an outdoor quiz-game (ZippyGO)?

In the following we will present the literature that has enlightened our study, the method of inquiry and present the results from our data collection before we conclude and suggest further research.

2. Theoretical Foundation

We assume that in their training for becoming teachers, they touch upon themes as outdoor learning, and how pupils can learn with and from each other, and how competition and games may contribute towards pupils' learning. We have also investigated how they perceived to develop the questions for the quizzes and sought theory from organizational learning theory.

2.1 Outdoor Learning

Outdoor learning has proved to be beneficial regarding social relations in the class (Jordet, 2010). And although longer outdoor arrangements are more effective regarding behavioural issues, being outdoor still has an impact (Dillon, Rickinson and Teamey, 2016). This is the secondary school and according to Ballantyne and Packer (2002) these students enjoy exploring the surroundings and have new experiences. Outdoor learning activities should, however, be planned and the students should be prepared in order to get the most out of the experience (Dillon, Rickinson and Teamey, 2016).

According to Lai (1999), students should be allowed to explore on their own rather than having a teacher controlling them. Areas where children feel relaxed offer the feeling of freedom, these are the environment that support conversations (Fisher, 2013).

2.2 Learning From Groupwork

Social learning theory supports the idea of learning with and from peers (Vygotskij, 1978). Coordination and cooperation are significant in small groups as it gives them the ability to function well (Rapanta, 2023).

Moreover, small groups allow pupils to take part in other pupils' knowledge, skills and experiences (Terwel, 2003). They may also be able to verbalize what they think, for example to be the right answer, without having to wait too long to be heard (Terwel, 2003; Fisher, 2013). The immediate response is something pupils sometimes need, in order to stay focused and alert. In a classroom with up to 30-40 students it is not acceptable behaviour to demand to be heard (Fisher, 2013). Pupils in a classroom are encouraged to wait until it is their turn, but sometimes their attention span is not sufficient for this wait.

Planning for a group task should then involve presenting a common purpose, so that they "share, discuss, argue, rationalize, find solutions and come to decisions together, just as they did in their earlier years when playing together was a more fluid and spontaneous affair" (Fisher, 2013, p. 132).

As children develop in different pace and ways, fixing groups for collaborative learning may not be optimal (Fisher, 2013). When children are allowed to organize the groups themselves, trust and security are two major keywords (Fisher, 2013, p. 135).

2.3 Quizzing for Learning

Quizzing is a way of gaming and games have been used for learning purposes for several decades (Hubbard, 1991; Salen, 2004; Stobbart and Evans, 2014; Slyman, 2018). Games are engaging, offer competition and may be immersive.

Yang et al. (2021) call quizzing "testing" and "test-enhanced learning". Testing facilitates for several learning advantages and is not only "an assessment of learning, but also an assessment for learning"(Yang *et al.*, 2021). Longitudinal research at the Inland Norway University of Applied Sciences, Norway, where another (indoor) quiz-game have been used, the students claimed it to support their learning outcome from courses (Haave and Vold, 2018). Research conducted with adult students showed that quizzing is perceived as motivating as it provides a competitive and fun approach to learning (Haave and Vold, 2018). In this study, the students from the "Research Methods" course cooperated together and developed some questions for the quizzing game. An example of a question is : "Which of these data collection methods are qualitative? A) Survey, b) e-mail interview, c) personal interview, d) collecting statistics". The class was divided into groups and each group developed some questions each from a designated chapter in the textbook from the curriculum of the Research Methods course. This was

very well perceived, both developing the questions and doing the quizzing, and they claimed to have learned both from developing the questions and from the quizzing itself.

2.4 Inclusion and Engagement in Development

In the same study as presented above, the students were engaged in developing the quizzes, something they also claimed to be enhancing the learning outcome, but also being engaged 'involvement and inclusion' (Vold *et al.*, 2018). The teachers are encouraged to contribute towards the quiz game by providing their own quizzes from the curriculum they have been teaching. In our case study, it is about seeking to engage the teachers by involving them in the development of the quizzes. Involvement and inclusion are also a part of the theory of Learning Organizations (Lave and Wenger, 1991; Senge, 2006; Filstad, 2007, 2016) and about developing organizations (Jacobsen and Thorsvik, 2019) . As this can be compared to a development of a (small) part of their work, it is worth looking at this theory. Senge (2006) for instance, claim that team learning and personal mastery will aid in a development process. Lave and Wenger (1991) discuss how Communities of Practice (CoP) due may aid in solving problems. The team of colleagues may be the CoP they need to learn and to feel personal mastery, to have shared visions and to have shared mental models (Senge, 2006).

3. Methodology

We have treated this as a case study as it was tested out as a single case (Yin, 2014). We used mixed methods of collecting data, surveys (Dwyer and Slyman, 2016) and in-depth semi-structured interviews (Dalen, 2011; Jacobsen, 2015; Johannessen, Christioffersen and Tufte, 2020). We use an adaptive method to analyse the qualitative data from both surveys and the interviews. We studied data line-by-line, sentence-by-sentence using colour coding highlighting key themes within each section. We looked for hidden meaning & actions. Asking questions, engaging/interacting with data, such as *what influences teachers' perception of the usefulness of the game (ZippyGo),* why participants are expressing their views/experiences the way they did. We reflected on each data and examined it, pondering and re-inspecting it. These then accumulated to categories that made up our findings. At this stage, all the coded data were linked back to the literature.

This mixed methods approach (Creswell and Creswell, 2017) has provided us with valuable insights into what teachers' reasons were behind using an outdoor quiz-game and how their perception behind developing quizzes from their own curriculum.

4. Findings

The findings from the survey are based on teachers' responses where we inquired about how they perceived developing the quizzes (and answeres) and how they perceived using the outdoor quiz-game for their students. The answers were somewhat inconclusive as the respondents have very different opinions about quizzing usages. It ranges from very positive towards using out-door games, to less positive. The reasons given for the positive are that it represents something new, it allows pupils to work in groups outside and activates their braincell to engage further in learning.

Statements like "The pupils were excited about doing something we don't usually do, and they really like being outside"(Interviewee 1) and "I could tell that the pupils enjoyed the quizzing and that they had fun. The groups were discussing and laughing but seemed eager to beat the other teams" (Interviewee 2). This is supported by the theory on group learning (Lave and Wenger, 1991) and team learning amongst pupils.

On the negative side, it is mainly about the area the quiz-game is played as some of the controls were outside the physical area of the school. They expressed a lack of control of the whereabouts of the pupils when they exited the school area.

When it comes to learning, teachers' responses are again split. Two claims that learning in team is a good thing and being outdoor is also great for pupils as they may then learn in a different environment. This is supported by Jordet (2010) and Coates and Pimlott-Wilson (2019) who state that pupils may act differently in different environment and that social constellations may also change. On the other side, two of the teachers respond negatively when they heard about malfunctions in the app, something which may happen and which can obstruct learning, if the students can't be trusted to do the quizzing, or if the weather does not permit being outside. This is what Filstad (2007) calls lack of control of external elements and a reluctance to test novel ideas. These comments are to do about situations and issues beyond anyone's control. However, they do not question the play, fun and engagement regarding the game. Hence, they do not disclose any lack of a potential regarding learning outcome for the pupils when playing the quiz (Mayer, 2014).

When it comes to developing questions for the quizzing, most of the teachers picked questions from the curriculum being lectured the past few months. One teacher even made up a "trick-questions" and focused on having fun. A few teachers were enthusiastic about making questions for the quizzing, but some also found it hard to do extra work. In the open-ended questionnaire one of the respondents refer to it as "yet another thing we need to do on top of everything else" (Respondent 1).

Only two of the four teachers worked together when developing questions for the quizzing. The other teachers did not collaborate nor cooperate, and in the interviews, we were told that the time aspect was the reason for not cooperating. "We all had classes and the little time we had of common time was spent on more urgent matters" (Interviewee 2). This implies that working on developing the quizzes was not prioritized. Hence, there was no opportunities to working on this together.

While most of the teachers claim they will use it again, one is uncertain. The ones who wish to use it are positive towards the potential of the quiz-game and claim to wanting to take part in future projects. The one who is hesitant, is the same who expressed being reserved about letting the pupils move outside the school area.

Unfortunately, as there was little or no cooperation and collaboration between the teachers, we were unable to establish any development between the teachers as a result of developing the questions for the quizzing.

5. Conclusion

The study was to investigate teachers' perceptions behind using an outdoor quiz-game, how they perceived developing quizzes from their curriculum and how they perceived cooperating and collaborating to develop the quizzes. The teachers have very different approaches to using the quiz-game. The positive teachers are willing to test new and novel experiences and also believe that outdoor is a good environment for pupils' learning and development. The negative ones seem to problematise on what may go wrong, which are issues beyond their control. However, none of the respondents were negative towards the potential learning outcomes from the gameplay nor from using the quiz-game. Only two of the teachers worked together and developed questions for the quizzes. The others did not collaborate, hence, it was not possible to investigate if and how the collaboration would develop their work situation.

5.1 Further Research

The next project is already planned and will be a case study with a quiz-game that the teachers will have contributed towards both in North-Macedonia and in Norway. Included in this project, our next endeavour will be to follow up on this investigation further.

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Digital Educational Escape Rooms for Social Entrepreneurship: Identifying Design Choices for Educational Impact

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Abstract: Digital educational escape rooms (DEERs) can provide an engaging gamified learning experience for students that is easy to use and sustainable for teachers. Though well-established in the STEM fields, where escape rooms often call for students to apply procedural skills, escape rooms are also used across a range of subjects to impact durable skills and attitudes such as communication, collaboration, and critical thinking. This paper seeks to extend the application of DEERs into social entrepreneurship (SE) education by exploring the DEER design elements relevant to the SE field. This paper will focus on developing durable skills and attitudes associated with social entrepreneurship, an area of entrepreneurship that seeks to create businesses with positive social impact. To identify the relevant design elements in DEERs, we conducted a systematic literature review. The research question was "Which design elements of digital educational escape rooms are necessary to teach social entrepreneurship skills and competencies?" This current paper builds on this type of framework by highlighting the relationship between the components of a DEER and learning objectives, specifically those relevant to a social entrepreneur's educational context. For example, almost all papers reported successful collaboration in online groups. The authors also found that specific puzzle types were less important than the gamified context on impact on learning and skill development. Thus, the authors contribute to our understanding of how DEERs can relate to SE specific learning objectives, skills, and attitudes.

Keywords: Digital educational escape room, Social entrepreneurship, Teaching competencies, DEER design elements, Technology in education, Gamification

1. Introduction

The use of escape rooms as a student-centered pedagogical tool has been increasing in higher education since their inception in 2007. Escape rooms are team-based games in which players solve various challenges within a time limit. Escape rooms become educational escape rooms when they incorporate content learning objectives into the challenges and other elements of the escape room, such as into the narrative, puzzles, and hints. A recent review of escape rooms in higher education by Veldkamp et al (2020) found that in relation to teaching and learning goals, the use of an escape room had a positive impact on implementing active learning, increasing motivation and/or engagement, increasing content knowledge, and developing teamwork and communication. As educational escape rooms grow in popularity, so too does the use of digital educational escape rooms (DEERs) as a cheaper and less time-intensive investment for teachers (Makri, Vlachopoulos, & Martina, 2021). Thus, DEERs can provide an engaging gamified learning experience for students that is easy to use and sustainable for teachers.

This research focuses on this digital subset of educational escape rooms and further zooms in on their use in the field of entrepreneurship education. Making social impact and responsibly addressing grand societal challenges is important in today's world and there is a growing movement in higher educational institutions to foster the growth of social entrepreneurial skills in students (Miller, Wesley, & Williams, 2012). Escape rooms have a positive impact on the learning goals and competencies that are necessary for developing the skills to create social impact. However, to date there has been little focus on escape rooms and digital escape rooms in entrepreneurship education. A few related studies have looked at EERs to teach value creation (Maaravi et al, 2020) and social entrepreneurship (Brinia et al, 2020). In addition, Martina & Göksen (2020) reported a positive impact of EERs on the development of soft skills in entrepreneurship students. However, there is not yet sufficient insight into the educational learning theories and game-based learning to push the future development of the sub-discipline. This paper addresses that gap by looking at the impact of digital educational escape rooms on skills, specifically social entrepreneurial (SE) skills. This review will focus on the following social entrepreneurial skills: ability to problem solve; interpersonal communication skills; innovativeness and creativity; confidence to succeed at challenging task; and empathy. These are in line with the 35 social entrepreneurship competencies listed by Miller, Wesley, & Williams (2012) and feature among the top ten competencies as rated by SE practitioners in the same report.

Research Question:

> *Given the gap in research on DEERs in social entrepreneurship education, we asked the question ""Which design elements are necessary to teach social entrepreneurship skills and competencies through DEERs?"*

We conducted a systematic literature review to link DEER design elements to social entrepreneurship skills and competencies. This research contributes to our understanding of game-based learning and DEER design elements and their impact on entrepreneurial skill development.

2. Methods

To create the framework, we conducted a systematic literature review using the following databases: ERIC, Web of Science, and Scopus. These databases provide extensive access to journals in the social science fields, and in particular, the field of education. Search terms included the following terms digital, online, and virtual escape rooms, escape games, breakout boxes, puzzle rooms, exit games, gaming rooms, adventure rooms + education. Publications were then screened to exclude physical escape rooms, systematic literature reviews that only partly dealt with digital educational escape rooms, and contexts other than higher education. Publications that only designed as opposed to carrying out digital escape rooms were also cut. Publications were limited to English language peer-reviewed journal articles published between January 2019 and February 2023.

The authors then analysed the theoretical underpinning, design elements, and learning objectives of 38 papers on digital educational escape rooms.

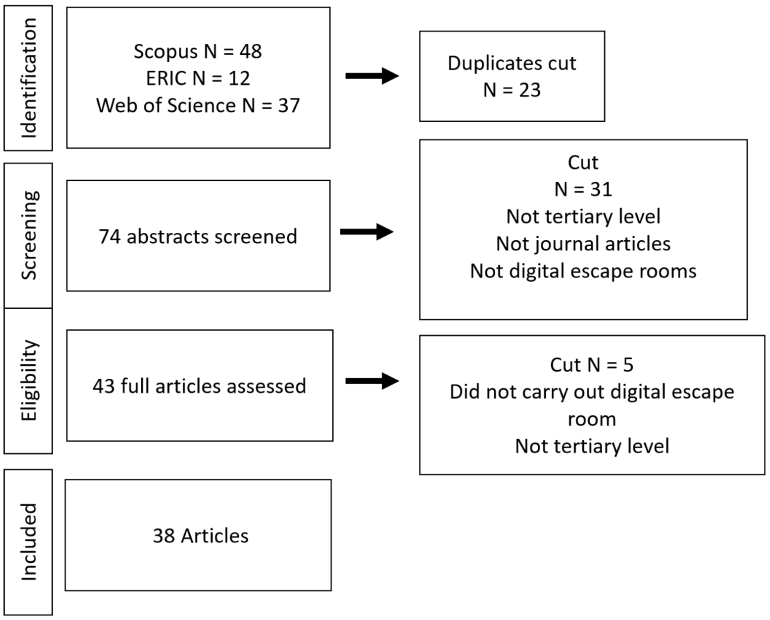

Figure 1: Article Selection Process

3. Data Analysis

The articles that were reviewed reported a mix of qualitative and quantitative data and reflected a variety of focal points. We used in vivo coding to categorize the data and find trends. The coding procedure is based on Miles & Huberman (2014) and the categories are below in Table 1.

Table 1: Coding Categories

Descriptive Analysis	
Subject area	Content area or field
Region	Global region for context
Study Type	Qualitative, quantitative, or mixed
Impact	Skill, Knowledge, Behavior, Attitude

Thematic Analysis	
Learning Theories	What theories of learning were reported as a foundation for decisions around the use of DEERs?
Design Theories	Which theories informed the design choices in the creating of the DEER?
Skills	What skills were educators trying to impact?
Impact measured	What skills and learning objectives were measured?
Impact reported	What skills and learning objectives were reported as impacted by the DEER learning experience?
Research questions	What topics and themes are important to the DEER community?
Design elements	What elements of the DEER were reported? Which design choices are important for effective DEERs?

4. Results

4.1 Descriptive Analysis

Digital educational escape rooms offer a versatile and less-resource intense gamified learning experience than physical educational escape rooms. DEERs are re-usable and once created, are quick to set up and carry out (Hursman et al, 2022; Smith & Davis, 2021). In addition, there are fewer space obligations as students can participate via online mobile devices. The various Covid-related lockdowns in 2020-2021 have played an important role in familiarizing teachers and students with the online environment, also leading to teachers experimenting with DEERs as a way to engage students not physically present in the classroom (Vestal, Matthias, & Thompson, 2021; Cates et al, 2020). 26% of the articles reviewed were published in 2019 and 2020. Twenty-seven (71%) of the articles reviewed were published in 2021 and 2022. 47% of the articles were from US institutions, 45% were from European institutions, and the remaining 8% were from institutions in Asia and the Middle East. See Tables 2 and 3 below.

Table 2: Year of Publication

Year	Number of Articles	Percentage of Articles
2019	1	2%
2020	9	24%
2021	7	18%
2022	20	53%
2023	1	2%

Table 3: Region of Publication

Region	Number of Articles	Percentage of Articles
North America	18	47%
Europe	17	45%
Asia	2	5%
Middle East	1	2%

4.2 Thematic Analysis

4.2.1 State of the field

The literature in the current review reveals that there is a wide range of DEER-related topics being addressed by higher educational institutions. The varied list of topics and their key themes highlight the diversity of questions that remain in the field. For example, five (13%) studies directly measured and reported gains in subject-specific learning outcomes, such as copyright and media law (Buchner, Ruter, & Keres, 2022), tobacco cessation treatment (Barrickman et al, 2022), balancing chemical formulas (Cai, 2022), calculus (Magrenan et al, 2022), and infectious disease (Dimeo et al, 2022). Eight (21%) studies sought to observe the impact of

DEERs on motivation, engagement, or interest, such as Bellés-Calvera & Martínez-Hernández (2022) who found that language students participating were motivated to communicate in the target language and Sanchez-Ruiz et al (2022) who showed that motivation was one of the most prevalent positive emotions reported by students playing a DEER. One article (2%) focused on specific design elements. Neumann, Alvarado-Albertorio, and Ramírez-Salgado (2020), found that asynchronous DEERs were comparable to physical EERs. Table 4 below provides an overview of the different focus points of the articles.

Table 4: Topics from Research Questions

Relevant Topics from Research Questions		
Question	Number of Articles if greater than 1	Percentage of Articles if greater than 1
Design		
What are necessary design elements?	2	5%
Does digital format work for escape rooms?		
Are asynchronous DEERs effective?		
Is instruction first necessary for an effective DEER experience?		
Is there a difference in perception of DEERS based on gender?		
Impact on Behavior or Attitude		
What is the effect on students' emotions such as stress or motivation or interest?	8	21%
Is a DEER a generally positive learning experience?	10	26%
Learning Theory		
Does productive failure play a role impact the efficacy of DEERs?		

4.2.2 Subject matter and learning objectives

In 2020, Hajar et al found in a state-of-the-art review that the majority of literature in the field of educational escape rooms came from the healthcare field. According to the current review, the use of DEERs in healthcare field is in line with those trends, with fifteen (39%) of the articles based on games within healthcare-related courses. Science and engineering were represented with nine (24%) articles, teacher training programs with four articles (10%), and language, history, and law with one article each (5%). Three (8%) studies failed to mention the content area. In addition to this range of content areas and content-area objectives, the majority (92%) of articles also reported behavioral or skill-related objectives such as increased motivation, collaboration skills, or critical thinking skills. For example, Barrickman et al. (2022) and Hursman (2022) reported a positive impact on communication in the context of interprofessional teamwork in clinical settings where healthcare professionals from different disciplines collaborate. For a full list of reported objective types, see Table 5 below.

Table 5: Objective Type

Objective	**Number of Articles**	**Percentage of Articles**
Skill-related Objective		
Critical Thinking and Analysis	9	23%
Collaboration and collaborative teamwork	10	26%
Communication*	8	21%
Problem solving and group problem solving*	6	

Objective	Number of Articles	Percentage of Articles
Teamwork	5	13%
Creativity and Innovation*	2	5%
Decision making and clinical judgement	4	10%
Behavior-related Objective		
Motivation and Engagement	7	18%
Confidence*	4	10%
Autonomy	1	2%

**Objectives identified in SE education*

4.2.3 Theories for game design

Fifteen (39%) articles did not report the application of a game-design theory to inform choices around game design. Within the context of designing puzzles or the DEER, nine (24%) articles mentioned the idea of gamification writ-large referring to the need make sure the DEER creates a game-like learning experience. However, no specific DEER design elements were connected to gamification. In one exception, Rodriguez-Ferrer et al (2022) applies the Mechanics, Dynamics, and Aesthetics model for game design to link content and skills with the mechanics and dynamics of the puzzles and to link aesthetics with narrative and immersion. Rodriguez-Ferrer et al concludes that each of these three components must have a connection to the learning objectives to be impactful. Six (16%) studies mentioned specific theories that informed the process of designing DEERs, such as the EscapEd framework for physical ERs (Clarke et al, 2017), Jenkins' (2004) Narrative Architecture, and the design cycle of Frederik and Sonneveld (2007).

4.2.4 Pedagogical theory

Fifteen (39%) articles did not include references to pedagogical theory to inform choices around including a DEER as a learning activity. Nine (24%) articles referred to gamification as a justification for the use of a digital escape room in an educational context and as a model for increased learning. These papers generally referred to the impact of gamification on knowledge retention and engagement. Other papers present gamification as a subset of active learning which is defined by Prince (2004) as learning that happens while students are engaged in activities. For example, Sanchez-Ruiz et al (2022) explicitly states that DEERs are a form of gamification and active learning that effectively creates a positive learning experience with increased learning. In addition to gamification as an approach to teaching and learning, Vestal et al (2021) highlighted constructivist theory and adult-learning theory as a framework for the application of a DEER. Constructivist theory emphasizes that learning happens when individuals create meaning through thinking and doing, for example through problem-solving (Bada & Olusegun, 2015). Adult-learning theory focuses on motivation for learning when individuals are engaged in problem-centered relevant activities (Merriam, 2008). Closely related to this is problem-based learning, applied by Gomez (2020) in which student teachers played and then created a DEER to meet learning objectives around problem-based and student-centered learning. Similarly, Heim, Duke & Holt (2022) referred to design-based learning in their report of engaging students in an ecology course in the creation of their own DEERs as a way of meeting content learning objectives. A last example is Ross and Hall (2021), who used DEERs as a stand in for simulation-based learning when face-to-face learning was not possible. In lieu of students practicing clinical work in a lab with mannequins, DEERs were found to meet the same application goals and to build student confidence.

In addition to pedagogical models and approaches, some specific theories of learning were also found. Dimeo et al (2022) applied self-determination theory to justify the DEER's impact on motivation. Rodriguez-Ferrer et al (2022) links the immersiveness of the DEER to its impact on learning via the flow theory. This theory refers to a state of flow, or intense focus, attained during gameplay in which information processing, and thus learning, is taking place. Finally, building on ideas around productive failure versus the limits of the cognitive load, Buchner, Ruter, & Kerres (2022) asked whether DEERs were more effective before or after explicit instruction. Productive failure is closely tied to problem-based learning and learning by doing and posits that deeper learning takes place through exploring a problem and potential solutions. The cognitive load theory, on the other hand, takes into account the limitations of working memory, with the implication for instructional design being that the working memory limits attention and what students are asked to do in an escape room

should take this limit into account. For example, instructions and game play should be clear enough that they do not impede the student's cognitive load and that their attention and working memory is focused on content-related questions so that they can process new information effectively. Buchner, Ruter, & Kerres (2022) concludes that instruction first leads to higher levels of knowledge acquisition and retention.

4.2.5 Emotions

Prieto et al (2021) explored the impact on the affective domain with pre- and post-tests before and after playing a DEER. Both positive emotions, such as satisfaction and happiness, and negative emotions, such as worry and frustration, were stimulated in players. However, there is no link to the specific game elements or impact on learning.

4.2.6 Puzzle types

The puzzle types shown in Table 6 is not exhaustive but highlights the wide variety of puzzle types applicable in digital educational escape rooms. Puzzle types were inconsistently listed throughout the literature and were never the focus of research questions. Therefore, the relation of specific puzzle types to impact on behavior or knowledge remains an area for further research. The fact that no papers specifically examined specific puzzle type in relation to behavior or knowledge suggests that the general consensus that DEERs can positively impact behavior or learning is not the result of the puzzle or question type, but a product of the gamified learning environment.

Table 6: Puzzle Type

Puzzle Type	Content Area	Conclusion
Single- or multiple-choice, drag-and-drop tasks	Copyright media law	Increased knowledge
Crossword, decode letter/numbers	Chemistry	Increased participation and motivation
Math questions, jigsaw puzzles	Nursing	Collaborative teamwork, critical thinking, knowledge-based retentions, self-confidence
Hidden object puzzles, code-breaking puzzles, logic puzzles	Engineering	Critical thinking, problem-solving, collaboration, teamwork, increasedknowledge
Crossword puzzles, unscramble words, decipher codes	Nursing	Increased knowledge, engagement, confidence, critical thinking, decision-making
geographical maze; anagrams, fill-in-the-blank, multiple-choice, or short answer	Nursing	Engagement, increased knowledge
MS and short answer questions, find hidden code	Nursing	Collaboration, engagement
Sorting, ordering, math, cipher, fill in blank	Nursing	Communication, teamwork

4.3 Towards a Framework for DEERs in SE

This paper sought to find DEER elements that focus on developing skills and competencies associated with social entrepreneurship, an area of entrepreneurship that seeks to create businesses with positive social impact. In line with research reporting on physical educational escape rooms (Tercanli et al, 2021; Veldkamp et al, 2020), reports in the field of digital educational escape rooms from 2019 – 2022 show the positive impact of DEERs on behavior and learning. However, research in this literature review fails to highlight specific elements of DEERs that play a role in developing targeted behaviors or skills. Furthermore, studies often reported similar impact on knowledge and skills despite varied choices in puzzle type, layout, and interaction capabilities. For example, Pozo-Sanchez, Lampropoulos & López-Belmonte (2022) measured the impact of physical and digital education escape rooms on different factors, finding that both positively impacted learning and engagement, while DEERs had slightly more impact on student's feelings of autonomy, creativity, and exploration. This suggests that the general gamified environment has more impact on learning than particular puzzle types or other game elements. Dittman et al (2021) compared team-based DEERs carried out with individual collaborating remotely or with the individuals together in the same room and found that each construct led to positive learning experiences and fostered collaboration.

4.3.1 Gamification, teamwork, developing skills

This literature review found no overwhelming evidence that decisions around the following DEER elements directly relates to the development of ability to problem solve; interpersonal communication skills; innovativeness and creativity; confidence to succeed at challenging task; and empathy: team size, play time, number of questions, puzzle type, or narrative type.

Turning our attention to the gamified environment and the role of social and active learning, research suggests that DEER design choices that optimize teamwork and collaboration may have the most impact on social entrepreneurship skill development. Anton-Solanas et al (2022) found positive impact on enjoyment and creative thinking and that teamwork, certain skills, and critical thinking were attained through participation in a DEER. They also found that participants with previous experience with commercial escape rooms rated the usefulness, impact on learning, and enjoyment significantly higher than those with no similar escape rooms experience. Lyman (2022) found increase satisfaction, self-confidence, and enjoyment in DEER participants and practitioners observed high rates of communication and collaboration. However, while all DEERs presented in the literature review except for one were team-based, the literature did not identify any other specific design choices for teamwork and collaboration.

5. Discussion

The top competencies in social entrepreneurship that this paper is interested in are the ability to problem solve; interpersonal communication skills; innovativeness and creativity; confidence to succeed at challenging task; and empathy. A growing number of research reports positive impacts on the ability to problem solve, communication skills, innovativeness and creativity, and confidence (see Table 4 above). Furthermore, it is clear that practitioners are increasingly using DEERs to impact these competencies.

In terms of which design elements result in the development of these competencies, the common thread is the gamified learning environment in which there is team-based collaboration. This is in line with constructivist theory and forms of problem-based or active learning. The literature does not yet show that specific narrative types, puzzle types, or other design elements specifically impact these competencies. In fact, positive results were found across DEERs with varying play design (synchronous vs asynchronous), narrative structure (imaginary vs real-life), play length, and types of puzzles (see Table 5 above).

6. Future Research and Limitations

There is a lack of a common reporting schema, resulting in a fragmented view of DEERs in practice. For example, in the literature reviewed not all authors report learning and design theories and not all authors report all elements of DEERS such as puzzle type, team size, or play time. Furthermore, not all competencies and skills are defined, leading to possible overlap of terms or fracturing of categories. For example, this paper combined critical thinking and analysis as one category, though some authors only reported on one and not the other. In addition, not all studies included pre- and post-tests and some results were based on small sample sizes and/or observation. Future research areas include the extent to which DEERs can build certain competencies, design elements with specific impact on learning outcomes, as well as understanding how to optimize collaboration in DEERs to best achieve goals around competencies. Exploration into neighbouring fields such as online learning and gaming may also provide insight into design elements for specific purposes.

7. Conclusions

In the past three years, there has been a significant uptick in the number of works published on DEERs. This literature review has provided an overview of the state of the field and the current important questions for the use of DEERs in higher education. DEERs are overwhelmingly found to have a positive impact on learning and on the learning environment, however, insight into specific and structured DEER design elements that is linked to impact remains limited. Research shows that DEERs are being used to impact skills and competencies that overlap with social entrepreneurial competencies, such as ability to problem solve, communication, and increased confidence. As such, there is a lot of potential for DEERs in social entrepreneurship education, though the need for a more nuanced understanding of the relationship between DEER design elements, a gamified environment, and the development of these skills remains.

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Multiplayer Serious Games Supporting Programming Learning

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Abstract: Computational thinking (CT) is crucial in education for providing a multifaceted approach to problem-solving. However, challenges exist such as supporting teachers' knowledge of CT and students' desire to learn it, particularly for non-technical students. To combat these challenges, Computer Supported Collaborative Learning (CSCL) has been introduced in classrooms and implemented using a variety of technologies, including serious games, which have been adopted across several domains aiming to appeal to various demographics and skill levels. This research focuses on a Collaborative Multiplayer Serious Game (MSG) for CT skill training. The architecture is aimed at young students and is designed to aid in the learning of programming and the development of CT skills. The purpose of this research is to conduct an empirical study to assess the multiplayer game gameplay mechanics for collaborative CT learning. The proposed game leverages a card game structure and contains complex multi-team multi-player processes, allowing students to communicate and absorb sequential and conditional logics as well as graph routing in a 2D environment. A preliminary experiment was conducted with four fourth-graders and eight sixth-graders from a French school in Morocco who have varying levels of understanding of CT. Participants were split into three groups each with two teams and were required to complete a 16-question multiple-choice quiz before and after playing the same game to assess their initial structural programming logics and the effectiveness of the MSG. Questionnaires were collected along with an interview to gather feedback on their gaming experiences and the game's role in teaching and learning. The results demonstrate that the proposed MSG had a favourable effect on the participants' test scores as the scores of 4 of the teams increased and 1 remained the same. All students performed well on the sequential and conditional logics, which was significantly better than the achievement of the Bebras test of the graph routing. Furthermore, according to the participants, the game provides an appealing environment that allows players to immerse themselves in the game and the competitive aspect of the game adds to its appeal and helps develop teamwork, coordination, and communication skills.

Keywords: Collaborative learning, Multiplayer Serious Games, Game design, Computational Thinking, Introductory programming

1. Introduction

Collaborative learning is an approach to teaching and learning where students work together in groups to complete tasks and promotes a positive learning atmosphere where interaction and negotiation trigger learning (Chowdhury et al, 2018). The use of computers to promote collaborative learning has been extensively researched, with a recent focus on using game environments as a learning framework. Moreover, game-based learning has evolved due to the introduction of advanced technologies, resulting in the deployment of Serious Games (SGs) in various fields and for a wide range of audiences. By managing interactive variables inside game environments, learners can build an intuitive grasp of the desired knowledge.

Multiplayer Serious Games (MSGs) combine the potential of serious games with collaborative learning processes, helping to develop teamwork and collaboration skills. However, the use of SGs in education raises questions regarding how to align desired learning outcomes with game objectives and features, and whether they can promote education. There is a risk of overemphasizing motivational factors, which could undermine intrinsic motivation. If the entertainment aspect of the game dominates all aspects of the game, students may lose focus and disengaged from the learning process, but if the game isn't appealing or amusing, students will lose interest and thus won't understand the full game. The creation of effective SGs requires the application of advanced technologies and thorough research into game design that can effectively combine educational and entertainment goals.

In this paper, a collaborative multiplayer Serious Game which is adapted from the unplugged game Robot City (Kuo & Hsu, 2019; Hsu & Liang, 2021) and enables game-based collaborative learning for programming is proposed. The targeted audience is students at an elementary school. The approach aims to study the impact of collaborative learning on computational thinking (CT) knowledge and skill sets by implementing a multi-team, multi-player system in a card game-structured MSG. The purpose of this research is to provide a practical framework for integrating programming content into multiplayer game gameplay dynamics and aims to answer

the following research question: 1) How can Computer Supported Collaborative Learning (CSCL) and Serious Games be used to support the teaching of Computational Thinking?; 2) How effective is the Collaborative Multiplayer Serious Game (MSG) in improving the programming skills and CT understanding of young students?; 3) How do the gameplay mechanics of the digital version of the card game impact the engagement and motivation of learners in improving their computational thinking skills?

2. Related Work

SGs are classified into different taxonomies based on multiple variables, including the application domain, target audience, skillsets, and intended learning outcomes. Squire et al (2004) presented 'Supercharged!', an SG with the primary goal of teaching physics, notably electromagnetism, to both higher education and high school students. To achieve the objective, players employ electromagnetism physics laws to propel their spacecraft and navigate inside a 3D dimensional world by inserting charging particles. Rooney (2012) used a serious game to promote in-house cleanliness to students aged 6 to 12. The proposed SG employs a similar atmosphere and characters to Half Life 3, a popular game at the time, with the user navigating through the 3D environment and completing in-house chores. This research emphasizes the importance of fidelity in SG.

Considering the context of collaborative learning, the integration of a multiplayer system component within an SG is an important addition and provides means for learners to interact with each other during the game. Interaction can be either cooperative where players cooperate in terms of resource sharing to complete tasks, or competitive where the players compete against each other to achieve the best results with specified performance evaluation metrics such as score and time (Wendel et al, 2012). There are many parameters to be taken into consideration when choosing between the types of interactions at the initial stages of the game conception including the game environment, the number of players targeted, player communication and social issues (Wendel et al, 2016). The major parts of design guidelines are discussed by Zea et al., (2009). Five essential aspects for effective collaborative work have been identified, which include: collaborative learning through group processing (enabling groups to exchange ideas and share progress), social skills development, positive interdependence (using a well-designed matchmaking system to create mutually beneficial groups), promotive interaction (encouraging and acknowledging each player's achievements), and individual accountability (providing sufficient individual feedback and monitoring for each student).

Recently, several MSGs have been developed for education. Garzotto (2007) proposed a cooperative MSG called Pirates Treasure Hunt to introduce European elementary school students aged 7-10 years to different cultures, Seah et al. (2018) developed a nutrition and health education game using Bingo and Lo et al (2013) proposed VocaMomo, an MSG to teach English vocabulary using a combination of Monopoly and Scrabble. The usage of existing popular games as a base for the serious game is a common pattern. Several studies have recorded the usage of the online platform Second Life to assist seminar activities, lectures, and other educational activities. Through the provision of unique support for distributed groups, online virtual worlds have outstanding capabilities for promoting effective distance learning using online chat systems and document sharing (Anderson et al. 2010).

The teaching of programming topics to young children raises debates about the most efficient ways to teach this content. Chang et al (2010) implemented a multiplayer serious game for assessing student's Java programming skills where players complete in-game tasks to receive gold/experience and reveal parts of the village map. The tasks range from multiple-choice questions to writing Java code. Moreover, Shabalina et al (2017) proposed a serious game for teaching programming skills to university students. The gameplay consists of finding and executing code to move a snake across the map to fulfil tasks to get rewards. Players can use a team chat to discuss strategies. This type of game is changeable or customizable as the snake game could be substituted with a car racing game or any other type of game. Malliarakis et al (2013) implemented a serious game to introduce programming to young pupils. The gameplay takes place in an action-adventure environment where a team tries to defend a castle whilst another team attacks it. To move across the map, the teams must succeed at finding the right pseudocodes related to the in-game environmental situations using the drag-and-drop tools provided. This provides the learners with a deeper understanding of the mechanisms involved in the pseudocode.

3. Methodology

To support computational thinking, the game Robot City (Kuo & Hsu, 2019; Hsu & Liang, 2021) was adapted into a digital game using Java. The board game taught structural programming concepts, such as sequential, conditional, and repetitive structures to help seventh-grade students learn computational thinking. The digital version, which is called Online Robot City, retains the same gameplay mechanics but also features a manual

grouping procedure, a 2D gaming world, and in-game features including a chat system to enhance communication between the game's various stakeholders. Players can learn programming concepts while engaging in immersive gameplay, allowing them to apply their computational thinking skills in a fun and interactive way.

To successfully integrate programming content into multiplayer game gameplay dynamics, a practical framework must be provided to make decisions about the necessary components of the design of MSGs. To begin, mechanics must be developed to specify what players can and cannot do in the virtual world and it is important to strike the correct balance between learning outcomes and entertainment. The proposed multiplayer serious game was created using an MSG design framework proposed by Yusof et al. (2010). This is a conceptual model framework for game designers and educational practitioners to employ when creating serious games for academic learning. The framework combines learning and educational theory with gaming requirements. The overall structure of the framework is comprised of 2 major sections: (1) the matchmaking system and (2) the game environment. The matchmaking process takes place in the lobby, which is illustrated in Figure 1. Players select tables that correspond to the games they want to play. A minimum of four players (2 per team) are required to begin a game, and sockets are opened for each user at this stage to signal the start of each session. Users are instructed to wait until there are four players before the game begins.

Figure 1: Robot City lobby

Following the matchmaking, the players join the game environment shown in Figure 2. The game's core concept is for players to work together in teams to collect resources on the grid and complete tasks. An intra-team chat system is shown at the bottom right of the screen. At the beginning of the game, each player is dealt eight cards as a starting hand. These cards will be used to navigate around the board's grid and collect resources and materials to fulfil tasks. At the end of each round, a new set of cards is selected. For the development phase, as shown in Figure 3, there are two degrees of card complexity: level 1 sequential cards and level 2 conditional cards. The sequential cards include basic operations such as move forward, backward, left, right, and U-turn and the conditional cards involve more intricate programming tasks, such as turning left if a barrier is in front.

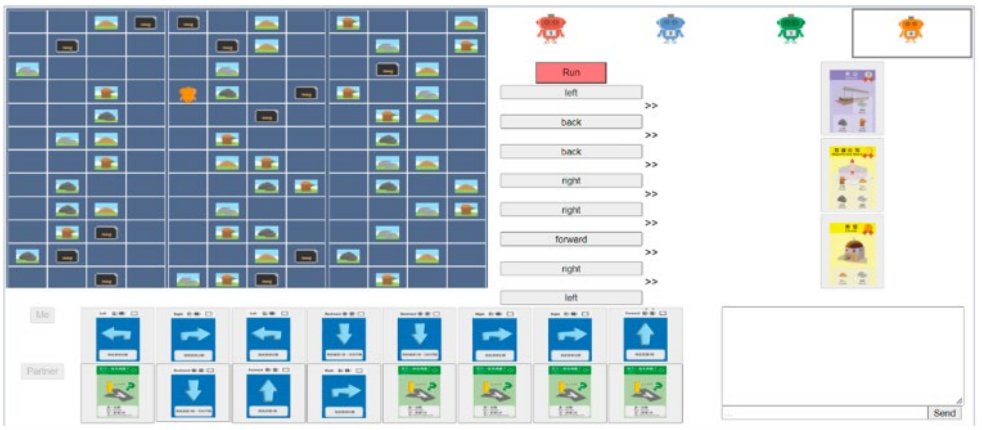

Figure 2: Robot City game environment

Figure 3: (a) Level 1 Sequential cards and (b) Level 2 conditional cards

Each player can exchange cards with their teammates and select up to 8 cards per turn to traverse around the board. The commands associated with each card are executed in the order specified by a computation complexity system. As a result, the robot walks in an appropriate direction collecting resources (sand, wood, stone and steel) which are arranged on a grid. Furthermore, construction cards are used to depict the mission that is allocated to players at random. Each card depicts a structure as well as the materials required for its construction. As shown in figure 4, each card has one of three levels of difficulty. The higher the difficulty of the mission, the more material is required to make it but the higher the reward associated with it. The grid contains different components including the GPU which is the player's robot's starting place, a sim card which serves as a doorway for players to teleport from one sim card to another, and a barrier which represents an obstacle.

Figure 4: Construction cards (3 levels of complexity: Level 1 – 3 points, Level 2- 5 points, Level 3 – 7 points)

4. Preliminary Experiment

4.1 Participants and Experiment Procedure

A preliminary experiment was conducted to evaluate the effectiveness of Online Robot City. This study involved 12 participants (4 in 4th grade and 8 in 6th grade) from a French school in Morocco. The participants (5 Male, 7 Female, aged 9-12) were divided into three groups based on age, with each group consisting of four students. Within each group, two teams were formed, with two students in each team. Groups 1 and 2 consist of 6th grade students and Group 3 consist of 4th grade students.

The study consisted of three phases: a pre-test quiz, gameplay, and a post-test quiz. Participants were asked to complete a 16-question pre-test quiz (Kuo & Hsu, 2019; Hsu & Liang, 2021) comprising multiple-choice questions before starting the game to assess their initial programming skills. The test items included three dimensions which are sequential logics, conditional logics and the Bebras test of graph routing. After playing the game, participants completed a post-game quiz containing the same questions in different sequence, and the results of both quizzes were compared to determine any differences in grades. In addition to playing the game, participants also provided feedback on its use by completing a 33-question questionnaire. The questionnaire collected CT scales for computer literacy education using a 5-point agreement scale (1 = completely disagree, 2 = slightly disagree, 3 = neutral, 4 = slightly agree, 5 = completely agree) with 18 items in total. There were 6 items for collecting cognitive loads with 7 point Likert scale; in the meanwhile, there were 9 items for collecting the perceptions of users. Furthermore, the participants were interviewed to also obtain their feedback on their gaming experiences, preferences for game elements, and the game's role in teaching and learning.

4.2 Results and Data Analysis

Pre-test scores for each group in Figure 5 reveal that students have varying levels of understanding of algorithmic thinking and problem-solving. Furthermore, compared to the 4th grade students (Mean = 7.5, S.D = 0.5), the 6th grade students had a deeper understanding of computational thinking and problem-solving (Mean = 11.5, S.D = 1.12) because IT and numerical sciences was introduced in 6th grade.

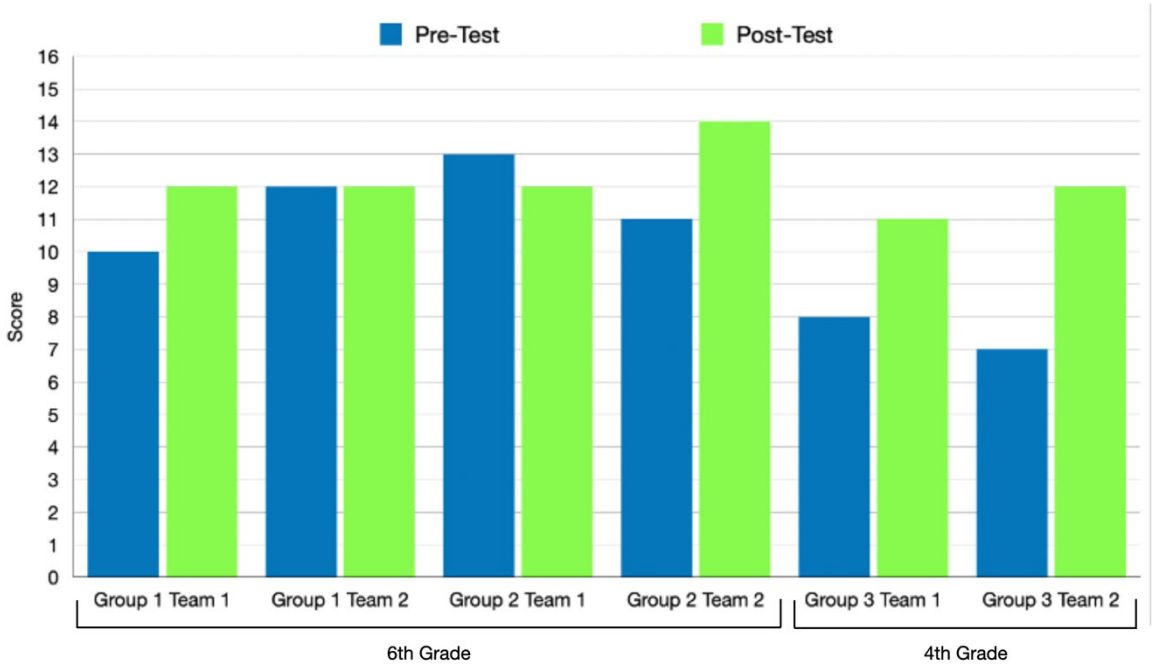

Figure 5: Number of correct answers for each time in the pre-test and post-test quizzes

After taking the pre-test quiz, participants were introduced to the game mechanics and rules before engaging in the gameplay phase, which lasted around 1 hour and 30 minutes. During the trial phase, participants were only issued with level 1 sequential cards, which include forward, backward, left, right, and U-turn. Players were able to immediately immerse themselves in the gaming experience because the operations were simple to understand and did not face any technical issues in joining the tables assigned to them. Each team was given only one easy task (a construction card composed of 2 materials). Some players began to communicate with each other, trade cards, and travel around the map, however in general there was still little communication between stakeholders. Only the two teams in Group 2 were able to collect enough resources to complete the missions. Despite the players being acquainted with the game rules and cards during the pre-test quiz, some struggled during the game suggesting the game environment interface was a bit confusing.

After the trial game was completed, the players were given a more detailed explanation of how the scoring system works. The gamers were then placed in real scenarios. Each squad was given three missions at random. For 6th graders, the game lasted around 60 minutes, while for 4th graders, it lasted about 40 minutes. Figure 6 presents the score achieved by each team. It is worth noting that team 2 of group 2 achieved the highest score but team 1 could not solve any missions and received 0 points potentially due to team 2's strong performance. In group 3, team 1 completed only 1 mission with a total score of 3 and team 2 could not solve any. When placed in the real scenario game, the participants more often used the chat system and were conversing with one another about gaming problems, discussing their working relationships, and assisting and boosting each other's success. Some groups implicitly had a team leader and seemed to do better than those that did not. For the teams with leaders, instead of focusing on their individual tasks, they were discussing strategies and collecting resources for each other. Players had to coordinate their actions because of the diverse resources, and they had to help each other because of the card swap option.

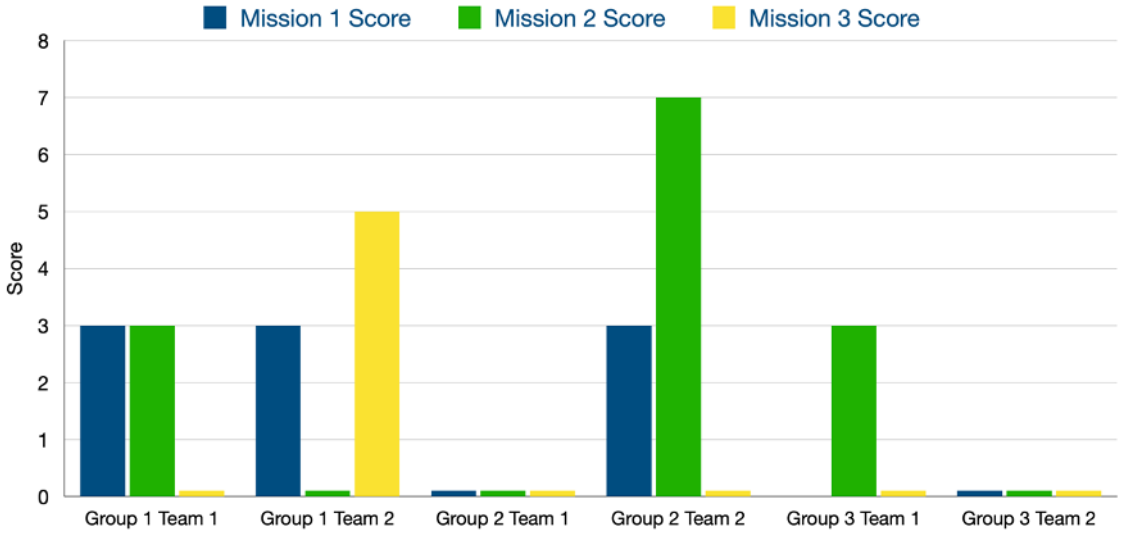

Figure 6: Scores for each team for each mission

Following the gameplay, each team took a post-test to assess their performance concerning computational thinking after playing the game. As shown in Figure 5, apart from Team 2 of Group 1 who achieved the same score, and Team 1 of Group 2 whose score dropped by one, the rest of the teams had different levels of score improvements. According to figure 6, although team 1 of group 2 and team 2 of group 3 both got zero points in all of the missions, the different performances of their opposing teams effected their learning performance differently in the post-tests. In other words, team 2 of group 2 got the highest scores in missions 1 and 2 because of their good game performance which brought them to the highest post-test score. However, this might have caused team 1 in the same group to feel frustrated and confused during the gameplay causing their post-test score to fall slightly.

After comparing different topics in their post-test, it was found that the correct rate of sequential logics was significantly higher than the correct rate of Bebras test of graph routing ($Z=-2.214^*$, $p=.027<.05$). In the meanwhile, the correct rate of conditional logics was also significantly higher than the correct rate of graph routing ($Z=-2.226^*$; $p=.026<0.5$) based on the results of Wilcoxon signed-rank test which is a non-parametric statistical hypothesis test.

For collecting feedback on the game and its role in teaching and learning, the participants were also required to respond to a questionnaire. Participants were first asked about their learning background and how they approach solving complex problems. When asked if when solving problems, they usually try to find the key points of a problem to understand it better, 7 (58.3%) of the participants strongly agree and 5 (41.7%) agree, and when asked if trying to apply familiar solutions helps to solve complex problems 7 (58.3%) of the participants strongly agree, 3 (25%) agree and 2 (16.7%) strongly disagree. Furthermore, when asked if they usually split large problems into several smaller ones, 7 (58.3%) of learners strongly agree, 2 (16.7%) agree and 3 (25%) are neutral.

The average effects of CT literacy are shown in Table 1 by employing the questionnaire developed by Tsai (2021). The five dimensions are evaluation (Cronbach alpha = 0.83), Abstraction (Cronbach alpha = 0.81), Decomposition (Cronbach's alpha = 0.74), Generalization (Cronbach's alpha = 0.75) and Algorithmic Thinking (Cronbach's alpha = 0.77). The overall reliability of the CT scale for computer literacy education (the value of Cronbach's alpha) is 0.91. The students performed well significantly on the generalization scale which is also normal distribution (K-S = 0.224; $p = 0.099$, $p > 0.05$) in the results of this study. Due to the small sample size, some scales like abstraction, decomposition and algorithmic thinking are non-normal distribution while the means of the abstraction and decomposition dimensions are both higher than 4 in the 5-point Likert Scale. The means of algorithmic thinking (M=3.85) and evaluation (M=3.97) are relatively low although both are higher than 3.5 on average. Overall, the results of the computational thinking literacy are good while the overall mean for CT literacy is 4.11 (SD=0.35).

Table 1: The descriptive statistics for computational thinking literacy scales employed from Tsai et al. (2021).

Scales	N	Mean	SD
Abstraction	12	4.29	0.37
Decomposition	12	4.03	0.59
Algorithmic Thinking	12	3.85	1.07
Evaluation	12	3.97	0.81
Generalization	12	4.33	0.48

Participants were asked about Cognitive Load based on the questions used by Wang et al (2014, 2020) and answered on a scale from 1-7 where 1 is ”very little” and 7 is ”a lot”. As shown in table 2, the effects of understanding the activity purpose and learning CT were both less than 4 (neutral). This suggests that the learning activities in the experiment were moderate. Also, distraction, stress and frustration were all less than 3 suggesting that the game didn’t cause mental overload to learners. The overall cognitive load is 2.67 on average (SD=1.42) with its overall Cronbach's alpha value of 0.836. The dimension of mental effort which is external cognition includes item 1 and item 2. The mean of mental effort is 3.25 (SD=1.67), referring to the fact that the instructional material is well designed. The dimension of mental load which is internal cognition includes items 3 to 6. The mean of mental load is 2.39 (SD=1.64), implying that the difficulty degree of the content is proper for the students.

Table 2: Responses to questions about cognitive load (N=12)

Item	Response (1: ”very little” - 7: ”a lot”)	Mean	S.D.	Median
1	How much effort was required to understand the purpose of the learning activity using this game?	3.42	2.07	3.5
2	How much effort was required to understand CT content in this game?	3.08	1.78	3
3	How much did this game distract you from learning CT?	2.08	1.08	2
4	How discouraged, stressed or irritated did you feel while using the game?	2.27	1.56	2
5	Were you frustrated whilst playing the game?	2.50	1.93	2
6	Were you frustrated at the end of the game?	2.42	2.27	1

An interview was conducted with team 2 of group 2, who were the group with the highest score, to collect more feedback on the game's functionalities and areas of improvement covering the topics of Computational Thinking and User Experience. Regarding computational thinking, according to these participants, the game provides an appealing environment that allows players to immerse themselves in the game and boost their focus. The competitive aspect of the game, which allows different teams and groups to participate, adds to its appeal. The chat service is a valuable feature that allows teams to communicate easily. More popup messages and hints would make the MSG gameplay more accessible. Other possibilities include modifying the grid background, for example, to vary the user interface.

5. Conclusion

Our design of a theoretically based collaborative serious game combines the theoretical knowledge of collaborative learning and game design into a practical application that takes advantage of game mechanics. The main aim was to create favourable conditions for collaborative learning and to structure players’ actions to maintain social interaction and collaborative activities. The multi-team multi-player board game utilizes game mechanics and rules to help players progress and achieve missions while implicitly injecting programming material into these rules, thereby enhancing their programming skills. The game also offers chat and card swap tools to encourage cooperation. The proposed MSG attempts to improve the learning processes by providing appealing, motivating, and effective tools that can also help students and teachers form meaningful relationships. The results demonstrate that the MSG had a favourable effect on the participants, as they were able to increase their test scores and reported high levels of satisfaction with its entertainment value.

This study has demonstrated the effectiveness of SGs thus far, but the potential of SGs for instruction providing compelling plots and contexts in which players can effectively and efficiently acquire new knowledge where progress can be accurately verified is still unrealized. However, this study is a first step towards creating a common language and understanding among instructional and game designers and the MSG designed to teach programming has yielded positive results and has proven to be both efficient and engaging. Recognizing educational game design trends is necessary to align educational and game design viewpoints. As a result, our goal will be to better recognize and define collaborative game design patterns so that they can be used more widely. The implications of different game design patterns on the establishment of collaboration and social interaction will be the subject of our future research.

In the future, a variety of strategies for improving the user experience can be examined and applied. For example, the game may benefit from more storytelling to boost user participation and comprehension and other services, such as audio queues can also be introduced to help teammates communicate more effectively. In addition to the conceptual improvements, the programming material could also be enhanced. The introduction of more complex card operations (levels 3, 4 and 5) will make the gameplay more interesting. The board game version is currently printed in Chinese only so that the conventional material could not be put into experiment in the French school. In the future, when the board game made of paper is also printed in different languages, it is encouraged the schools in Europe to do further empirical studies and to compare the different effects between the board game version and the digital game version. This will allow the students to hone their critical thinking skills whilst playing the game. Another goal of a follow-up study would be to evaluate the influence of such games on each student's knowledge acquisition process to regular in-class activities. To ensure adequate evaluation, the proposed game should be performed on a bigger sample. We did not assess any progress in social skills like teamwork, coordination, or communication, but we did see that the participants employed all of them during the game. This suggests that with the right game design, such talents can be explicitly improved.

Acknowledgements

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Exploring the Effects of Progression Mechanics in Competitive and Collaborative Gamified Learning

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Abstract: This study investigates how competitive, collaborative, and progressive game-based and gamification learning mechanics influence children's motivation, engagement, and learning outcomes. The research was conducted with primary school children in an e-learning context delivered by the University of Central Lancashire's (UCLan) eLearning platform – Learnvoy - and specifically explored how the sense of progression, competition, and collaboration in a gamified environment influenced learners' academic performance. This study involved groups of primary school learners in a quasi-experiment. The control group engaged in a traditional eLearning setup where they were asked to watch a few plain monologue tutorial videos and answer related questions. Two experimental groups participated in a gamified eLearning environment that used the same tutorial videos, but in which their answers powered up in-game characters: in one case creating a competitive experience and in the other a collaborative experience. After viewing each tutorial video, each learner answered the same questions as the control group, but here their rate of correctness powered up, or hindered frogs, from reaching a princess in a game based on the story of The Princess and the Frog. In this way, competitive, collaborative, and progressive elements were introduced in the game, where learners with higher accuracy in the question and answering activities had a better chance of winning, thus fostering an environment of motivation and achievement. The results indicate that both experimental groups exhibited improved motivation, engagement, and accuracy compared to the control group; there was no significant difference between the two gamified conditions. These results are interesting to schoolteachers and eLearning creators seeking to integrate innovative and effective learning strategies into their educational curriculums. The findings underscore the potential of competitive and collaborative game mechanics, particularly progression elements, in enhancing learners' learning experiences and outcomes. In conclusion, this research highlights the educational value of competitive, collaborative, and progressive digital game-based learning mechanics, suggesting that the sense of progression, competition and collaboration conveyed by such games can play a role in fostering learners' academic success.

Keywords: Competitive gamified learning, Collaborative gamified learning, Progressive gamified learning, Lesson gamification, Learner engagement, Learning progression embodiment

1. Introduction

Traditional forms of learning can sometimes be seen as passive and potentially unengaging, especially when they involve activities such as listening to lectures or reading textbooks without interactive components. This passivity and lack of engagement is one reason why educators and researchers are interested in more active and engaging teaching strategies, such as digital game-based learning (DGBL), a type of learning where games are used to deliver educational content, and gamification, which involves incorporating game-like elements into learning (Al-Azawi, Al-Faliti and Al-Blushi, 2016). Whether DGBL or gamification is implemented online or offline, the principles of how they operate, and their potential impact on learning and motivation, remain largely the same. As online learning requires self-motivation and self-directed learning from students (Stark, 2019), it is hypothesised that DGBL or gamification can help support these aspects and bolster engagement (Fatta, Maksom and Zakaria, 2019).

This study began with a literature review on engagement within games, digital game-based learning, and gamification, leading to the creation of a PEG (Progression Embodiment Graph) illustrating the relationship between progression, feedback, and engagement. This graph then informed the design of a novel gamification setup. Through experimental testing, this setup demonstrated improved engagement outcomes, as shown by the collected data.

2. Literature

2.1 Why Engagement is Important

Learner engagement is widely recognised as a crucial factor in successful learning, as it promotes learning retention and fosters a positive learning environment (Kahu, 2013). Research has consistently shown a positive correlation between learner engagement and academic achievement. Engaged learners generally perform better academically (Schunk and Mullen, 2012) and for primary school aged children, engagement in learning is a predictor of future academic success (Ladd and Dinella, 2009).

2.2 Engagement in Games

The game industry has extensive knowledge about creating engaging experiences, as creating engaging products is the key to surviving. If players find a game engaging, they are more likely to continue playing it over time, potentially leading to higher revenues from in-game purchases, advertising, and other monetisation strategies (Hamari, 2015). One aspect that makes games engaging and sometimes addictive is their provision of immediate feedback. Feedback often comes in the form of scores, progress bars, level-ups, rewards, or direct responses to the actions that players take. This instant feedback is an essential factor in player engagement as it allows players to see their progression in real-time, which can be rewarding and motivating (Juul, 2010).

Instant feedback in games can be considered both an extrinsic and an intrinsic motivator, depending on the context and how the player interprets it. As an extrinsic motivator, instant feedback often comes as rewards or penalties. The desire to achieve these rewards is driven by external factors. As an intrinsic motivator, it provides players with a sense of mastery and competence. This form of motivation comes from within the individual, who is driven by the satisfaction derived from personal achievement and the inherent enjoyment of the task itself (Ryan, Scott and Przybylski, 2006). Since the feedback mechanic in games can be simultaneously extrinsic and intrinsic, and a combination of intrinsic and extrinsic motivation tends to be most effective, it provides one explanation for why some games are so engaging or even addictive (Ryan and Deci, 2000; Przybylski, Rigby and Ryan, 2010).

In education, the idea that timely feedback on progression is crucial also prevails. The longer a delay between a learner's action and the feedback on that action, e.g., submitting an assignment or answering a question, the less likely the learner will make a strong connection between their action and its outcome. This can reduce their engagement and motivation in the learning process (Stott and Neustaedter, 2013).

2.3 Engagement in Digital Game-Based Learning

The DGBL field draws heavily from principles of game design and psychology to create engaging and educational experiences (Van Eck, 2006).

Figure 1: Prodigy – a screenshot taken from prodigygame.com in 2023

DGBL inherits the instant feedback mechanics from game design to motivate learning, as it allows learners to see the immediate impact of their actions and encourages them to adjust their strategies and efforts to improve their outcomes (Plass, Homer and Kinzer, 2015; Zeng et al., 2020). The feedback provided closely relates to the game's storyline or objectives. For instance, Prodigy is an online digital game-based learning platform for grades 1-8 that covers over 1,400 crucial math skills. As students play, they answer maths questions to progress in the game. Players who make a mistake may take damage or face other in-game consequences. Figure 1 is a screenshot from Prodigy, where players answer questions to defeat enemies. The embodiment of progression is presented as the health bars.

2.4 Engagement in Educational Gamification

While aligned to motivate and engage learners, educational gamification can offset some of the challenges inherent in DGBL. Gamification typically involves adding game elements such as points, badges, or leaderboards to existing learning activities, which can be less resource-intensive (Al-Azawi, Al-Faliti and Al-Blushi, 2016) and potentially less distracting. For example, a point system can be directly tied to learning objectives. The points

accumulate quietly in the background and do not require prompt reactions from the learners, reinforcing rather than detracting learners from the educational content.

Duolingo is a language learning platform that uses gamification extensively. It uses a path to embody learning progression (Figure 2) which acts as a motivator (Sun and Hsieh, 2018).

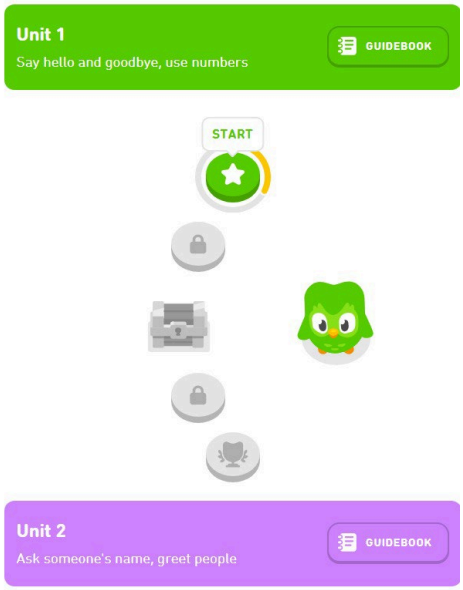

Figure 2: Duolingo – a screenshot taken from duolingo.com in 2023

To implement gamification well, incorporating elements that drive intrinsic motivation and foster a sense of progress and competence is essential (Kapp, 2012).

3. PEG (Progression Embodiment Graph)

3.1 The Relationship Between Progression, Feedback, and Engagement

Setting aside the various deliveries of blended game elements and learning context, the elements underlying engagement are feedback time and progression embodiment, as the above literature review indicates. The relationships between these elements are shown in Figure 3. In this graph, the X-axis is feedback time which is the time between the learner completing a task and the 'system' giving feedback on whether this is correct or not. The Y-axis is progression towards the completion of the learning task. Together with the starting point 0, their coordinate produces an engagement angle. The bigger the angle is, the more engaged the learner is. For example, if it takes 100 years to learn a subject, the engagement angle will be very close to zero. However, if it takes 1 second to complete the learning, the engagement angle will be close to the maximum and would represent an activity that individuals could embark on and complete immediately. The 100% progression doesn't necessarily represent the entirety of the learning journey. Instead, it can apply to any subset of tasks within the larger learning process. Furthermore, this progression can be visualised or represented in various forms. If the embodiment of progression can convey a combination of intrinsic and extrinsic motivation, it will enlarge the engagement angle.

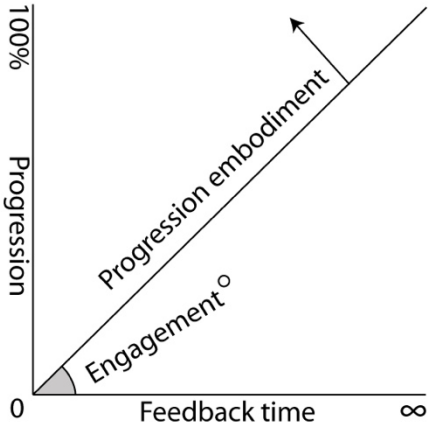

Figure 3: The PEG (Progression Embodiment Graph)

3.2 Research Question and Hypothesis

Ample research indicates the positive impact of immediate or timely feedback on learning progression. In our research, we explore the effect of additional intrinsic (collaboration) and extrinsic (competition) on engagement as measured by recall tests and self-report. The question being answered is *'Does the addition of motivating game elements have an effect on learning, and if so, is there a difference between competitive and collaborative game elements?'* Our hypothesis is that '*For a simple focused learning activity, the addition of a game, that offers additional intrinsic or extrinsic motivation, will result in greater engagement as measured by recall tests.'*

4. The Study

4.1 Participants

The study took place at the UCLan Mess Day event in 2023. Fifty-four children aged between 8-9 participated on several different days. Only four claimed to be non-native English speakers, but he/she did not struggle with the lesson. The control group consisted of 26 participants. Two experimental groups each had 14 children in them.

4.2 The Learning Materials

Since the hypothesis is related to the gamification of education, a teaching subject had to be selected. It was important to choose something that the participants were not already familiar with, while also ensuring it was easy to understand to ensure learning takes place. The anticipated participants were Year 5/6 pupils, and according to the National Curriculum in England: primary curriculum, Big Data was a topic not explicitly covered in their curriculum. However, some elements of data science are included in computing, mathematics, science, geography and history courses (England Department for Education, 2023), so in this case, the participating children should know something about data but little about Big Data. Therefore, Big Data was chosen as the topic to present to the participants. The participating children were going to be aged between 8 and 9 and as it is accepted as a guide that a child has an attention span of 2 to 3 minutes per year of their age Altun, Hazar, and Hazar (2016), the learning activity for this was intended to only take around 20 minutes. The topic was divided into four lessons, each lasting around 5 minutes. Each lesson consisted of a one-minute video tutorial and a four-minute question-answering section. The four Big Data videos are Introduction (1:02), Collecting (1:07), Analysing (1:10) and Applying (1:36). There was nothing especially technical in the videos, only brief descriptions of Big Data in those four areas.

4.3 The Gamification – Integrating a Small Game Alongside the Lessons

The next step was to create a small game to integrate alongside the lessons as a motivator. The main functionality of the game was to convert the correctness rates of children's answers into progressions. Integrating a game into the eLearning environment positions our approach at the intersection of DGBL and gamification. However, since the game itself didn't contain educational content and its gameplay didn't directly facilitate learning, but primarily served as a mechanism to reflect learners' progression, it leans more towards gamification.

Like most games, the game needed a storyline and objectives. The fairy story 'The Frog and the Princess' was chosen as the background: *Once upon a time, a frog kissed a sleeping princess, and the frog turned into a prince. Now another princess had been found sleeping for a long time. The whole frog kingdom heard the news, and all*

male frogs started heading towards the princess's castle. A prince of the neighbour kingdom received the report and set off immediately to rescue the princess, but it took time. Before the prince's arrival, the castle launched missiles to push back the frogs (Figure 4).

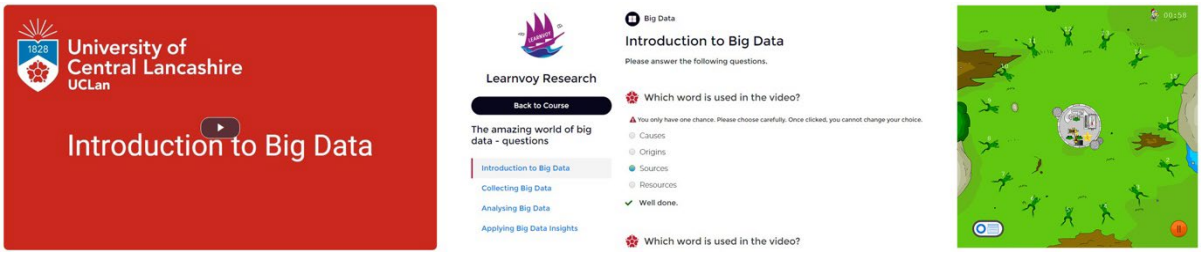

Figure 4: The learning experience structure - video – questions – game; repeated four times

Competition and collaboration were chosen as the vehicles of extrinsic and intrinsic motivation (Abuhamdeh and Csikszentmihalyi, 2009; Kong, Kwok and Fang, 2012). Therefore, there were two modes of the game which were studied in the two experimental conditions. In one mode, the participants played as the frogs (competition) and the other as the castle missile (collaboration). Hence we could explore if there were any differences between competition and collaboration in engaging the participants. The nature of interaction in competition and collaboration guided the design of the two modes. That is, in the competition mode, participants work against each other, trying to be the best in the group, and in the collaboration mode, participants work together to achieve a common goal.

4.3.1 The competition mode

For the participants who played as frogs in this game, each frog had a number above them. A user ID could be found at the top of the website. The participants could identify their frogs by associating the ID and the frog number. The accuracy of their answers powered up the resistance of the frog. The more questions they answered correctly, the less distance the missiles pushed back their frogs. If one reached the castle before the prince arrived, that person won the game. When the participants powered up their frogs, they competed to reach the castle.

4.3.2 The collaboration mode

For the participants who played as a team, they powered up the missiles launched by the castle in the game. Initially, the missile speed was very slow. The accuracy of their answers increased the speed of the missile; the faster the missile, the quicker it could push the frogs back. If the children playing survived until the arrival of the prince, they won. When the participants powered up the missile, they collaborated to keep the frogs away from the castle.

4.3.3 The embodiment of progression

After watching each of the four learning videos, the participants answered the questions and then watched how their characters performed. In each learning section, they saw their frogs getting closer to the castle or the castle missiles pushing the frogs back. The distance between the castle and the frogs in the competition mode and the speed of the missile in the collaboration mode are the embodiments of progression.

4.4 Instruments for Measuring

4.4.1 Recall questions to measure engagement

Memory and attention are often considered early indicators of engagement; if learners are paying attention, it is likely that they are engaged. Similarly, if they can recall information, it is likely that they are paying attention (Alves Durães, 2018; Sarter and Lustig, 2009). Memory can be easily measured through recall tests (Roediger and Karpicke, 2006), which can be easily managed by eLearning systems, likewise UCLan's Learnvoy. Hence, it was decided to apply recall tests to measure engagement in this study. Questions consisted of two types only: direct memory and memory with context. For the direct memory, the question was, "Which word is used in the video?". Consistency was kept in plural, singular, and tense for answer options to match the words used in the videos. For the memory with context, to avoid guessing the answers, the incorrect options still sounded plausible (see Figure 4).

4.4.2 Experience survey

A short survey was designed to get feedback on the learning, and on the two game modes (see Table 2) and to capture children's experienced fun (Read, MacFarlane and Casey, 2002). An open-ended question was used to elicit opinions on whether children would recommend the game to their peers.

4.5 The Participant Groups

The participants were divided into control and experimental groups. The control group took the lessons without gamification, and the experimental groups learnt with gamification in one of two modes: competition and collaboration (Figure 5).

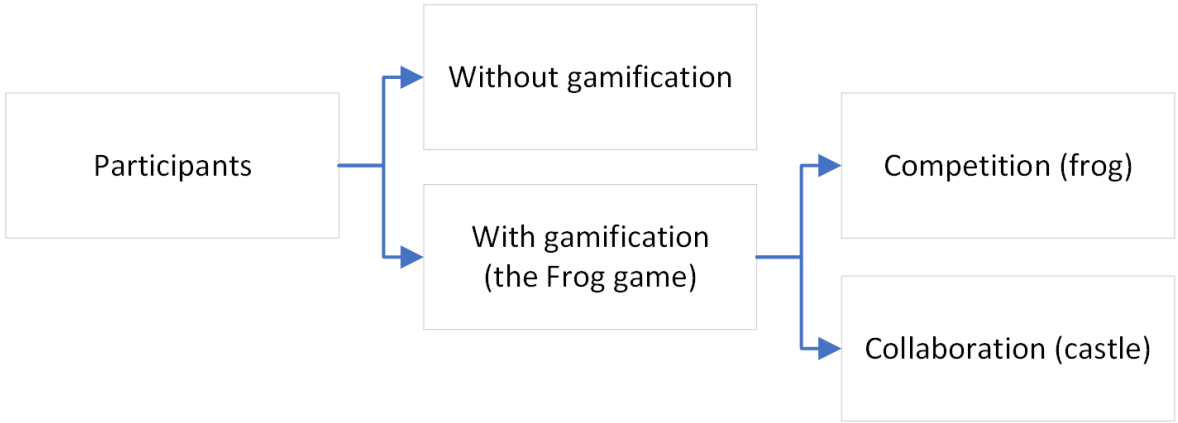

Figure 5: Participant groups

4.6 Procedure

Children came to the University labs to do the study. They were greeted in the labs by a senior researcher who gave a talk about safety and about assent, stressing that children could choose to not participate if they wanted to. Children were put into groups to complete a series of different activities on the day. The present study was the only activity that was concerned with learning and Big Data and children came to it in groups of between 12 and 15. After sitting down at individual PCs attached to the University network, which had the software installed, an instruction video was played to the children to inform them what they should expect and do. Each group that came to the session did a different set up – two groups did the control condition with no gamification (26 children) and the other two did the competition (14 children) and collaboration (14 children) experimental conditions. Children were placed into mixed-ability groups by the teachers; each followed the following steps:

- Step 1: Answering personal questions – Children were asked if they knew about Big Data and about their first (native) language. These questions were only used for screening as any child who claimed lots of knowledge about Big Data, or who had very poor English, would have their data excluded.
- Step 2: Watching videos - Children watched the first of four videos about big data.
- Step 3: Recall Questions - After watching each video, children were given the password to unlock the questions to answer relevant questions from the video. To encourage attention and discourage picking an answer randomly, participants only had one chance to answer each question. This was also designed to emulate a gaming experience, where each decision can result in either rewards or repercussions. After completing the answers, the two gamification groups were taken to the frog game to see how their answers powered up the characters in the game.
- Step 4: Repeat Steps 2 and 3
- Step 5: Experience Survey

5. Results

Assuming all variables were the same for all the groups and only the designed gamification was employed to reinforce engagement (Figure 6), the two gamification groups were expected to answer more questions correctly and express greater appreciation for the experience than the control group.

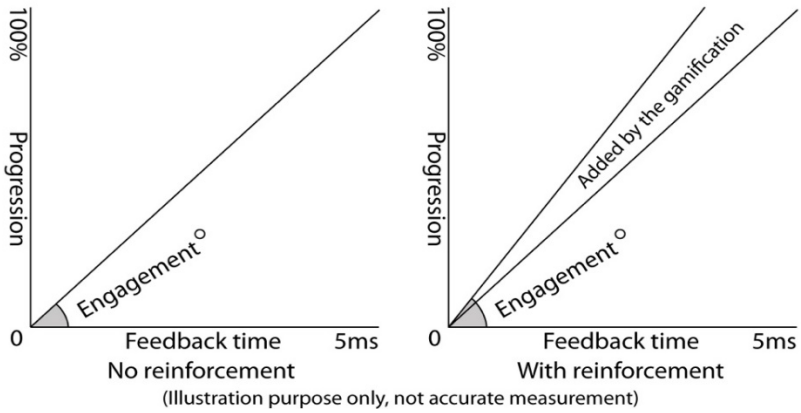

Figure 6: Engagement reinforced by the designed gamification.

5.1 Learner Performance

Each correct answer from a child was scored as 1 point and a score recorded for each of the four instances of answering. Given that the child only experienced the game after having answered the first set of questions, any effect of the game on answering would be expected after that moment – viz. there would be shown to be an effect if the scores for the last three videos from the experimental groups were significantly better than the scores of the last three videos from the control groups. Similarly, if the scores for the first video were not significantly different across the three groups (control and two experimental) then we could surmise that any effect seen from gamification as independent of the group make-up. Table 1 shows the percentages of all correct answers across the groups.

There was no significant difference between the performance of the experimental groups (M = 3.5, SD = 1.02) and the control group (M = 3.31, SD = 1.17) in the answers to the first set of questions, $t(52) = -0.634$, $p = .529$. This can give confidence that the children in the different groups were not especially different in their ability and focus at the start of the activity.

Table 1: The accuracy of answering the questions from each group.

	Control group	Competition	Collaboration	Both gamification groups
Introduction	55.13%	58.33%	58.33%	58.33%
Collection	54.49%	59.52%	59.52%	59.52%
Analysis	67.95%	77.38%	72.62%	75.00%
Applying	57.05%	78.57%	64.29%	71.43%

The experimental groups (M = 12.36, SD = 2.38) performed significantly better in their answers to the final three sets of questions, $t(52) = -2.423$, $p = .009$, than the control group (M = 10.77, SD = 2.34) which answers the first part of the research question in regard to improvements in performance being made with the addition of the gamification.

For the second part of the question, a comparison was made between the scores on the last three sets of questions between the two experimental conditions. Despite higher average scores, there was no significant difference, $t(22) = 1.262$, $p = .218$, between the competitive condition (M = 12.93, SD = 2.55) and the collaboration condition (M = 11.79, SD = 2.04). This answers the second part of the research question but also suggests that this would merit further study.

5.2 Children's Experience

Subjective opinions were gathered from all the children about learning with the videos and the question / answer protocol and the gamification groups (collaboration and competition) were additionally asked about the experience of having the frog game associated with the learning activity. Table 2 shows that about 80% of the participants reported being motivated, by the games, to engage in the learning activity.

Table 2: The percentages choosing Yes to the questions.

	Competition	Collaboration
Did the frog game make you want to pay attention more?	85.71%	84.62%
Did you want to answer more questions right because of the frog game?	78.57%	84.62%

An open-ended question in the survey asked: Would you tell your friends to play this game? Why or why not? This is an optional question. Generally, the majority said, "Yes, it is fun", which matches the enthusiasm when the participants took the lessons. The feedback from the competitive group was eleven positives and one negative. "No" was the comment from the negative one. The feedback from the collaboration group was nine positives and four negatives. The four negative comments are (with the children's typos):

- "No, because it's not a true game that people would play because it's a learning game."
- "No, because there are other learning that teach different things."
- "No, because it was about work."
- "I don't really know because I don't know the name of the game."

This feedback suggests that children preferred the competitive set up for the game.

6. Discussion

It appears that the addition of a small game to create higher engagement might assist children in learning. The groups who experienced the games scored more highly on the last sections of the learning activity suggesting that there was an effect. It is not clear what this effect was – it could be that the game created more intrinsic or extrinsic motivation – as was theorised or it could be that simply having that break in the learning created a better learning experience. Further studies would be needed to investigate this. On the face of the scores (see Table 1), adding competition seemed to have a greater effect on learning but given the small numbers and the lack of any significant difference, this would need to be studied with larger samples. Other studies on motivation in digital games (Lomos, C., Seineke, U., Kesting, F. and Luyten, J.W., 2023) suggest that systems that promote extrinsic motivation (like competition) have a negative effect on building students' intrinsic motivation and so an interesting follow on to this work is to explore how collaboration can be built into the learning activity. One important feature of our work is that the game is an add-on to the learning activity – that is to say, that the scores power the game. Using the same protocol with other learning activities is an obvious follow on, as is using it with other children. Of interest in both these cases might be to see how collaboration and competition relate or differ in keeping children focussed and on whether different ages exhibit differences.

Our research question was answered in so far as it was shown that gamification improved learning and this supported our hypothesis. Returning to the PEG, children's self-responses as well as the learning data showed an increase in engagement as theorised.

7. Conclusion

This study tested the hypothesis that '*For a simple focused learning activity, the addition of a game, that offers additional intrinsic or extrinsic motivation, will result in greater engagement as measured by recall tests.'* This hypothesis was developed from the conclusion of the literature review on the relationship between progression, feedback time and engagement. Engagement was measured through recall tests. In the study, the focused learning lasted for around five minutes in each lesson, four lessons in total. Whether five minutes is the optimal length remains unknown, but the data gathered shows the feasibility of the hypothesis.

The participants aged 8-9 came from four primary schools and were divided into control and experimental groups. The experimental group was further divided into competition and collaboration groups. Based on the quantitative data gathered, the experimental group achieved better scores than the control group, and the qualitative data testify that the participants were motivated to engage in the setup guided by the hypothesis.

This research provides a foundational stone for further gamification study in this direction. The research data indicate a preference tendency between the competition and the collaboration modes, which can be the next step of the research. More components can be added to this gamification method later to enrich the booming of blended teaching – the mixture of traditional and online teaching after the impact of Covid-19.

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On Supporting Game-Based Learning via Recommendations

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Abstract: Over the last two decades, game-based learning has gained increasing popularity. In today's world, teachers are expected to utilize technological tools such as digital games as learning aids. Despite the multitude of studies examining the benefits of game-based learning, finding the most convenient game for a particular teaching purpose can be a challenging task given the vast number of similar games that are available on the market. With this study, we aim to provide teachers with a recommendation system that will assist them in selecting appropriate games from all the web-based game materials available. A key theoretical premise behind this work is to examine teaching from the perspective of teachers to develop their ability to teach. The purpose of this study is to develop a recommendation system that will assist teachers in selecting educational games based on the subjects they teach, that will be both personalized and use the experience of other researchers at the same time. We propose a system that utilizes the latest developments in signal processing and machine learning, specifically the tensor completion method. This is a machine learning technique from the family of collaborative filtering methods that fills in missing values in a dataset by analyzing its existing patterns. According to our knowledge, this is the first study to modify a collaborative filtering approach to develop a recommendation system for game-based learning. Whenever a teacher requires a recommendation, the method leverages other users' ratings on games, while also considering the teacher's previous experience with the system. Accordingly, the system selects the best games for users based on their previous preferences as well as the experiences of other users. It appears that this system has a reasonable chance of working properly without excessive training samples, which could not be achieved through other advanced machine-learning techniques. The experimental section demonstrates the potential for such a proof-of-concept technique, which uses tensor completion; even with a small number of collected data, performance starts to increase in suggesting games to the specific user, and this trend is promising for big data.

Keywords: Game-based Learning, Teacher education, Recommendation systems, Interactive learning

1. Introduction

A closer examination of the traditional methods of education, such as direct instruction and textbooks, reveals that these methods dominated the education process before the 21st century. Since technology has gradually transformed instructional methods over the last 20 years, educators now have many tools to use technology effectively in the classroom. Consequently, game-based learning has become an influential part of modern education. Games for students are not particularly new and have been used for many years mostly in early childhood education, but the concern that arises in this domain is the need to integrate games into the design of modern educational approaches at all levels. In addition to the game factors themselves, researchers and practitioners should focus on the instructional support of the game. Goals can be set to promote learning or to guide students to visualize learning outcomes (Pivec 2007).

The web itself cannot address the needs of students due to a large amount of inaccurate information on the web. Computers, on the other hand, cannot motivate students because technology is already at the center of their lives. Moreover, games are commonly linked with fun, but researchers indicate the need for game-based learning is not related to its fun feature (Mattheiss et al., 2009). Educational games could be used to engage students to test theories and achieve objectives. All these technologies (web, computers, digital games) can be used in collaboration to make game-based learning, particularly valuable (Kiili 2005).

The most challenging point in game-based learning integration is that teachers are outraged when considering how to find the most convenient games for their classrooms. The main practical problem is that there are countless games claimed to be educational. However, teachers do not have time to search them all and find the appropriate ones. This research targets at finding a solution to this problem to make game-based learning to be more favorable for teachers.

Dealing with educational games from teachers' point of view, there are challenges, and the efficiency of game-based learning depends mainly on the acceptance by the teachers (Bourgonjon et al. 2013). Therefore, it is important to motivate teachers to implement games regularly to obtain a more engaging learning environment. Hence, our goal in this study is to pursue a recommendation method for teachers to perceive the appropriate games for their students among the huge number of instructional games on the internet.

A major challenge in providing a recommendation system is the vast number of course topics and games. While teachers can differentiate between many categories of courses, it's difficult for them to manually categorize all

the relevant games for each topic. Additionally, each teacher has their own teaching style, which can affect their preference for certain games even within a single course topic. It's not possible to assign a game to only one specific course topic. Therefore, using a rule-based approach to prune irrelevant games based on assumed differences between course topics is not practical.

Indeed, in this proof-of-concept study, we collected data from physics teachers to score games on 19 course topics. As can be seen in Figure 2, their response may differ for some games and course topics (details in the experimental setup section). Last, but not least, almost every day, a new educational game may be developed and released. It is practically infeasible to maintain manually a way of identifying games according to your needs. To sum up, in this paper, we focus on designing a *personalized automatic recommendation system*, which could both use other users' experience with the games to be proposed, and a user's previous experience with other games in suggesting games according to course topics and teaching style of the user.

Only a few studies focused on recommendation systems for educational purposes, for example, personalized learning plans (Hulpus, Hayes, and Fradinho 2014) reading materials (Hsu, Hwang, and Chang 2010), students' academic performance (M. Goga, Kuyoro, and N. Goga 2015). To our knowledge, this study is the first in the literature that shows a recommendation system that can be designed to help teachers in finding the appropriate games easily according to the chosen set of topics by the teacher.

This research constitutes a relatively novel area for game-based learning with a breakthrough method for teachers and instructors. We suggest the use of matrix and tensor completion techniques to build a model that could recommend online games, and simulations, in order to assist teachers to incorporate game-based learning. In the proposed recommendation system, a teacher chooses a set of course objects, then, according to this choice, the system retrieves a list of games. To do this, the system first predicts the scores for the new games, i.e., the ones the user has not experienced yet. By using both predicted and known scores, the system returns a list of games with the best scores. While calculating the scores for unseen games, the technique both uses the scores of other users' scoring on the game of interests and the teacher's own scoring data on other games. In that sense, the system is personalized, the retrieved games highly depend on the teacher's own teaching style. Our model-based technique, exploiting ideas from signal processing, can work with a small piece of data (even one additional sample is enough), although preserving the increasing trend in accuracy when we increase training sample. This is also a clear advantage over more advanced machine learning tools, which requires a large number of training samples.

In the experimental part, we compare the proposed recommendation system, with a baseline in which only other users scoring is used. In that case, averaging of other users' scores about the game that is unseen by the teacher will be the technique we will compare with our algorithm. The experimental results show a clear advantage of such a personalized system over a system that is not personalized.

2. Background

The challenging part of using a recommendation system for education is that in a classroom there are a variety of students with different abilities and interests. Even if they study the same subject, their understanding levels are different. It is very critical to find a game that addresses all students' attention in a lecture to be able to incorporate them. Game-based learning provides a solution for K-12 students, but it is worthwhile to know what research says about the use of technology to guide a game-based course plan (Barnett 2001).

Lack of competence among teachers has always been a contributing factor to failures to integrate technology into the classroom over the last few decades (Eteokleous 2008). On the other hand, the number of games that can be used in classes depends on technological opportunities in that school. Teachers benefit from digital games for instructional preparation, during the process, or as a learning tool. Classroom activities, instructional materials, group work, homework and lesson plans are some of the main areas that teachers can integrate a game. While it is generally agreed that game-based learning can be beneficial for K-12 students, there has been argued that most of the games have failed in helping students to develop knowledge. On the other hand, some games have not been well designed, shallow, not attractive, or repetitive, and do not help students to find any possibilities for active exploration (Kirriemuir and McFarlane 2004). Many alternative methods are available for solving this problem, but they all require teachers' time, which is typically not enough, or even available.

Our work aims to develop a generic recommendation method that can solve a range of problems. In recent years, there has been rapid development in recommendation systems designed for specific learning groups. This has brought great opportunities in education. For teachers, an automated system that can guide activities and intelligently recommend online resources to enhance the learning process would be very useful. While

recommendation systems are typically used to increase profit by displaying services a consumer is likely to be interested in, our study focuses on student achievement and integration rather than satisfaction and profit.

3. Preliminaries

Collaborative Filtering and Matrix Completion

Collaborative filtering is a technique utilized by recommendation systems (Ricci, Rokach, and Shapira 2010). Specifically, collaborative filtering is a method to make automatic predictions about the interests of a user by collecting information from many users (Kang, Peng, and Cheng 2016).

It is based on the idea that people who agreed in their evaluation of certain data items in the past are likely to agree again in the future. For example, a person who wants to see a movie might ask for recommendations from users with similar taste in movies. The main steps of a collaborative filtering algorithm for producing a list of recommendations for a user are: (i) Find the most similar users to the user in question using a similarity function, (ii) predict a relevance score for each item not rated by the user based on his/her similar users, and (iii) recommend the top- n items with the highest relevance score.

Recommendation systems that include collaborative filtering typically require very large data sets, such as in the case of the Netflix movie recommendation system (Bennett and Lanning 2007). Collaborative filtering algorithms require the active participation of users; they consist of a system that reflects interest of users, and algorithms that are capable of matching up people with similar concerns (Koren, Bell, and Volinsky 2009).

Matrix completion is one of the most popular methods for recommendation systems and has become superior among collaborative filtering approaches. Matrix completion in recommendation systems may broadly be defined as the completion of a matrix with one dimension indexing users and the other dimension representing data items, typically products, to be scored. Following the dimensions, the elements in the matrix are also the rates that given by other users. To complete the matrix, the main focus is to find missing elements which are needed to be filled automatically by the algorithm because not every user is able to or wants to score every element in the matrix. Thus, there will be recommendations that make sense for users, depending on the items they scored previously and other people's scores on the current item of interest.

4. The Problem

As mentioned above, in collaborative filtering-based recommendation studies the most common problem definition is that the matrix to be completed is defined as a matrix with one dimension indexing users and the other dimension represents the products to be scored. In this work, we modified the classical target matrix construction strategy so that one dimension of the matrix is the context (topics to be learned during lectures), and the other dimension is the product to be scored (e.g., candidate games). This matrix is created for one specific user (teacher in this concept), then it can be completed by the help of other users' scoring matrices. This pre-assumption takes us from matrix representation to *tensor representation*. One advantage of defining such a model is that the system is able to give a satisfactory result even with a limited number of available scoring matrices, e.g., only several users with given scores to the candidate games. In the sequel, we will give a more formal definition of the proposed scheme. Then, we will discuss the mathematical formulation of the problem and the proposed solution.

Mathematically speaking, let's assume N number of games are needed to be scored with the pre-defined range of grades. We fixed these points from 1 to 10 according to what rate they imply each of the M numbers of course topics. The proposed recommendation system can be summarized as follows: A user (in our context, a teacher i) gives scores to a small subset of games corresponding to their involvement with the course topics. It is not feasible for a user (a teacher) to evaluate N number of games for M number of lesson topics, because the number of topics, M, and the number of games, N, may be excessive.

There are at least two possible cases that we can encounter in a realistic scenario. In the first case, even if a specific user able to score all the N numbers of games, he/she may leave empty most of the matrix elements, due to lack of attention, time, etc. Fortunately, the score of the course topics reflects very high correlations. Therefore, even if the user cannot score all the candidate games according to the topic, that is to say, do not fill the whole scoring matrix; it is possible to estimate the unfilled scores in the matrix using the filled ones.

In the second scenario, which will be our main concern, the teacher can score a limited number of games and may want to be suggested new games based on the topic he/she wants to teach in a course. In a real use case, we can assume that the number of candidate games N is too large. For this reason, we want to take advantage

of the scores of other users (teachers) and hence their scoring matrices. Let's assume that another user, teacher j, had already experienced some or all the candidate games that teacher i has not. If we can predict the possible scores that teacher i may give to these games by leveraging the data of teacher j, which is the scoring matrix of the teacher j, then we can recommend or not recommend these games to teacher i based on these estimated scores. Moreover, we can extend this scenario so as to have access to T number of scoring matrices of different users, to be used for estimating missing scores between each other. In this case, we have a tensor of data, whose each layer is nothing but a specific user's (teacher) scoring matrix. The corresponding tensor representation can be illustrated in Figure 1.

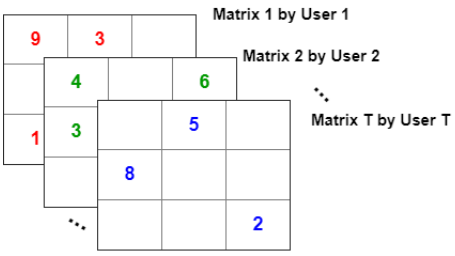

Figure 1: A representative tensor created for multiple users

5. The Method

The matrix completion problem is a well-studied problem in the signal processing literature (Cai, Candes, and Shen 2010), which is used extensively in recommendation systems (Koren, Bell, and Volinsky 2009). Specifically, let $X^{\{i\}} \in R^{M\times N}$ be the scoring matrix of the user i with available elements $\{X^{\{i\}}{}_{(g,k)}: (g,k) \in \Omega\}$, where Ω is the set of filled elements (scores) in the matrix. We can then define the missing elements, which are to be estimated, as the ones $\{X^{\{i\}}{}_{(g,k)}: (g,k) \in \Omega^C\}$, where Ω^C is the complement set of the set of available scores, Ω. One of the state-of-the-art matrix completion strategies is to solve the following convex optimization problem, which is also known as nuclear norm minimization,

$$\min_{M} ||M||_* \text{ subject to } M^{\{i\}}{}_{(g,k)} = X^{\{i\}}{}_{(g,k)}, (g,k) \in \Omega, \quad (1)$$

where $||M||_*$ is the nuclear norm of matrix $M \in R^{M\times N}$ to be estimated. The nuclear norm of a matrix is indeed nothing but the sum of the singular values of it. The importance of the usage of the optimization problem in Equation (1) is that it is the closest convex relaxation to the following NP-hard optimization problem:

$$\min_{M} \text{rank}\,(M) \text{ subject to } M^{\{i\}}{}_{(g,k)} = X^{\{i\}}{}_{(g,k)}, (g,k) \in, \quad (2)$$

which should spit out a solution matrix M which has maximum correlation between elements from all possible matrices with available elements are indexed by set Ω and missing elements with Ω^C.

In this work, we consider the tensor completion problem from the scored elements of tensor $\mathcal{X} \in R^{M\times N\times T}$, where i^{th} slice of $\mathcal{X}$ is the scoring matrix, $X^{\{i\}} \in R^{M\times N}$, of ith user. By leveraging the recently proposed tensor nuclear norm

(Lu et al. 2019), we can define the following tensor completion problem,

$$\min_{\mathcal{M}} ||\mathcal{M}||_* \text{ subject to } \mathcal{M}_{(g,k,l)} = \mathcal{X}_{(g,k,l)} \; and \; (g,k,l) \in \Omega, \quad (3)$$

where the solution tensor $\mathcal{M}$ is completed tensor with estimation of mixing elements, and $\mathcal{X}$ is scoring tensor that compose of T number of users with available elements $\{\mathcal{X}_{g,k,l}: (g,k,l) \in \Omega\}$. In this concept, Ω is the set of filled elements (scores) of $\mathcal{X}$. To solve the optimization problem given in Equation (3), we derived an alternating direction method of multipliers-based algorithm (Boyd et al. 2011).

For the sake of brevity, we omit the details of its derivation, but it can be seen in Algorithm 1. The steps of algorithm are explicit except the sub-problem we solve, namely:

$$\arg\min_{\mathcal{Z}} \left\{ ||\mathcal{Z}||_* + \frac{\mu}{2} ||\mathcal{Z} - \left(\mathcal{M} - \frac{\beta}{\mu}\right)||_F^2 \right\}, \quad (4)$$

which can easily be calculated using toolbox given in (Lu et al. 2019) ("Proximal operator of nuclear norm").

When a new instructional game is released, a user-specific prediction system first estimates the possible scores that the user of interest may give for these untested games (whose scores are represented as new columns in the scoring matrix of the user) via Algorithm 1. Then, if the user has already determined his/her topics of interest, Algorithm 2 recommends a pre-defined n number of games according to the maximum n relevance scores of all games. The mentioned relevance scores of a specific game are obtained by the summation of the scores corresponding to the determined topics (if multiple selected) within the column of the scoring matrix. Note that the retrieved recommended games can be from both already seen and scored ones, or unseen (new) ones.

Algorithm 1 Tensor Completion Algorithm

Input: $\mathcal{X}_\Omega$
Auxiliary variables: $\beta, \mathcal{Z} = 0 \in \mathbb{R}^{M \times N \times N}$
Tuning Parameters: μ
Initialize: $\mathcal{M}_\Omega = \mathcal{X}_\Omega, \mathcal{M}_{\Omega^C} = 0$
repeat

$$\mathcal{Z} \leftarrow \arg\min_{\mathcal{Z}} \left\{ \|\mathcal{Z}\|_* + \frac{\mu}{2} \left\| \mathcal{Z} - \left(\mathcal{M} - \frac{\beta}{\mu} \right) \right\|_F^2 \right\}$$

$$\mathcal{M}_{g,k,l} \leftarrow \begin{cases} 1 & \text{if } \mathcal{Z}_{g,k,l} < 1 \\ \mathcal{Z}_{g,k,l} & \text{if } 1 \leq \mathcal{Z}_{g,k,l} \leq 10, \text{ (Projection Part I)} \\ 10 & \text{if } \mathcal{Z}_{g,k,l} > 10 \end{cases}$$

$\mathcal{M}_\Omega \leftarrow \mathcal{X}_\Omega$ (Projection Part II)
$\beta \leftarrow \beta + \mu * (\mathcal{Z} - \mathcal{M})$
until Convergence
return $\mathcal{M}$

Algorithm 2 Game Recommender System

Inputs:
$\mathcal{X}_\Omega$:= Scored elements in tensor form,
Λ:= Set of target topics for the lecture,
i:= User index to be recommended,
n:= Number of games to be recommended.
1. Obtain $M^i_{(\Omega^C)}$ using Algorithm 1.
2. $\tilde{M}^i_{(\Omega^C)} \leftarrow$ Column-wise rescaling (to 1-10) of $M^i_{(\Omega^C)}$
3. Calculate the score of games, i.e., $\text{scores}(k) = \sum_\Lambda \tilde{M}^i_{(\Lambda,k)}$.
return the indices of games with top-n scores

In plain English, we consider the strong connection between topics, games, and user preferences during game selection. Algorithm 1 helps fill in missing elements in a tensor (specifically, unscored games), optimizing for maximum correlation while preserving user-provided scores.

When a user seeks game recommendations based on a topic or topics, Algorithm 2 retrieves the user's corresponding matrix from the estimated tensor. It identifies the column (representing a game) with the highest value for the selected row (representing a topic). If multiple topics are chosen, the algorithm finds the column with the highest average score across the rows. As Algorithm 1's estimation may not be perfect, Algorithm 2 normalizes the estimations column-wise before making recommendations.

6. Experimental Evaluation

Data Collection

19 universally common high school physics topics were determined in this study. As shown in Table 1. In addition, 10 arbitrary educational games were selected from 10 arbitrary websites. For ethical concerns, the names of the games are anonymized. Interested readers can contact the corresponding author. Furthermore, several teachers are asked to test the games and evaluate the efficiency of the games according to specified topics. 6 teachers gave feedback and fulfilled an Excel file. Participant teachers' level of experience is between 3 to 6 years, and

they all are 28 years old. Participant teachers are asked whether they used at least one educational game in their classroom before. The collected data can be seen in Figure 2.

Table 1
Topics that are used in the experimental evaluation part.

TOPICS	
1. Vectors	10. Potential & Capacitance
2. Kinematics	11. Direct Current
3. Newton's laws	12. Magnetism
4. Work, Energy, Power	13. Wave, Sound, Light
5. Linear Momentum	14. Atomic Nuclear Physics
6. Rotational Motion	15. Fluid Mechanics
7. Circular Motion & Gravitation	16. Thermodynamics
8. Oscillations	17. Universe
9. Electrical Forces & Fields	18. Relativity & Quantum
	19. Matter and Light

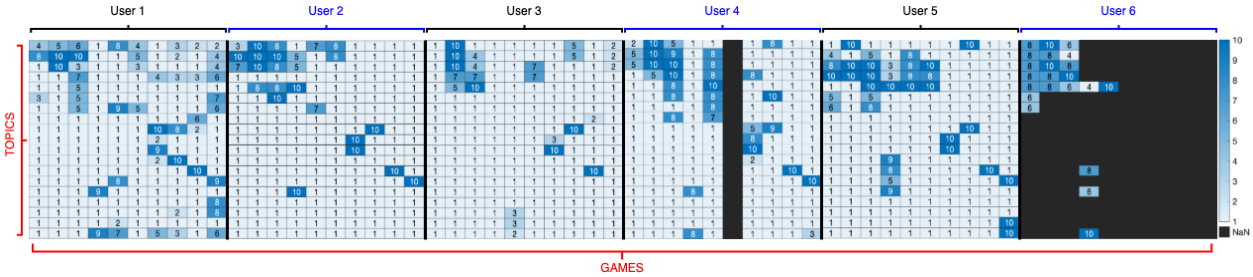

Figure 2: Data used in experimental evaluations. Six physics teachers played the games and sent their scoring tables, which are given above

7. Experimental Design

In order to test the proposed method, three columns were deleted from all matrices. Therefore, we mimic the situation such that the selected user never tried these games with corresponding deleted columns. The elements of the deleted columns were predicted by using Algorithm 1. Then, with these predicted scores, the games are recommended via Algorithm 2. Please note that Algorithm 2 recommends the n-number of games with top n scores. The number of recommended games, n can be pre-defined.

For the prediction of missing elements of matrix of user i, at least one additional user's data, who already scored these missing games, is used. The main purpose here is to see how the performance of the proposed method will change while the number of users who tried one or more games is increased. Thereafter to be able to predict the matrix of the user i, increasing number of matrices from other users were applied. By this means, the performance report was expected to be higher when five users' matrices are used to predict than the one user's matrix is used. These trends can be easily observed in reported performance given in Figure 3. The performance measure that can be seen herein for Algorithm 1, is determined as the Root Mean Square Error (RMSE) for the estimation of missing columns of scoring matrix of a specific user, namely teacher i. The RMSE value is calculated as follows.

$$\text{RMSE} = \sqrt{\frac{1}{|\Omega^C|}\sum_{j=1}^{|\Omega^C|}\left(\mathcal{M}_{\Omega^C}^{\{i\}}(:)_j - \mathcal{X}_{\Omega^C}^{\{i\}}(:)_j\right)^2}, \quad (5)$$

where Ω^C is the set of missing elements in the scoring matrix, thereby $|\Omega^C|$ is the total number of missing elements, and also $\mathcal{M}_{\Omega^C}^{\{i\}}(:)_j$, and $\mathcal{X}_{\Omega^C}^{\{i\}}(:)_j$ are j^{th} elements of vectorized version of the predicted scores of ith user and true values of them, respectively. RMSE is a widely employed performance metric for assessing the quality of estimations used in recommendation systems. A lower RMSE value signifies a superior estimate.

In order to show the performance of Algorithm 2, three random topics are selected and n number of suggestions are retrieved with the maximum scores which are calculated as relevance scores corresponding to selected topics. Recall that the games that are deleted were also selected randomly. While we get performance scores for both Algorithm 1 and 2, each experiment repeated thousand times and an average result is obtained for every one of them. In all the experiments, the tuning parameter, μ in Algorithm 1, was set as 0.015.

As a performance metric for Algorithm 2, we determined the probability of the success rate in n retrieval. The success in n-retrieval is the case where Algorithm 2 returns the game which is tried to be predicted (the game that gets the higher relevance score when the true scoring matrix of the user is available) within these n retrieved ones. As an example, when $n = 2$, the probability of success is the ratio of the cases where the game

which should be recommended is returned within 2 suggestions given by Algorithm 2, to the number of trials, which is 1000 in our setup as mentioned.

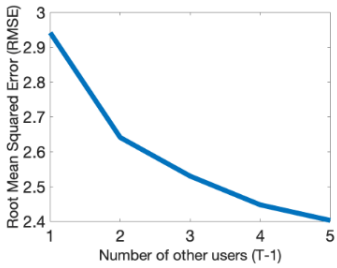

Figure 3: Algorithm 1 performance is reported as RMSE in estimation of missing columns of scoring matrix using data other users. When the number of other users increase (tensor size T), error in the prediction decreases rapidly

When we want to give suggestions to the ith user about arbitrary any topics in the list, we can use the data of other users. We expect that when we increase the number of additional users' data (therefore we increase the tensor size, T), the probability of success also increases. This situation can be seen in Figure 4. Figure 4-(a) shows the probability of retrieving the game that should be recommended when Algorithm 2 suggests only one game. Figure 4-(b) also shows the probability of retrieving this game when Algorithm 2 suggests two games. Likewise, Figure 4-(c) illustrates the probability of success when Algorithm 2 returns three games. The experimental results show that when the number of other users, which already scored the game of interest, increases the performance is also increases. And even with only 5 additional users, it can reach satisfactory results especially for top-3 suggestions are returned. The performance reports in Figure 4 are given as the average performance of situations where user i, whose missing columns need to be estimated, are chosen from the first 5 users, whose data are given in Figure 2. In averaging, User 6 is excluded because most of the columns were missing from the matrix. Nevertheless, User 6, matrix is still use-full in estimation of the other's matrices.

As a competitor method (baseline), we choose the method, where the scoring matrix's missing column estimation for i^{th} user is done by getting an average of the columns that belong to other users who already scored the games of interest. As Figure 4 shows, for all the cases, the proposed solution surpasses this baseline method. The reason why the proposed scheme gives a higher score is that the simple averaging (baseline) technique only uses the correlation among the scoring matrices of different users. However, the proposed scheme both implicitly leverages this outer correlation, but also the correlation within the matrix of the ith user itself. Therefore, the technique is user-specific.

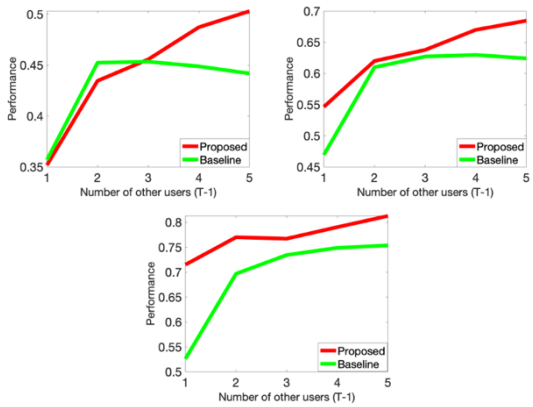

Figure 4: Performance reports of Algorithm 2 vs baseline method. (a) The probability of retrieving the game that should be recommended when Algorithm 2 suggests only one game. (b) The probability of retrieving this game when Algorithm 2 suggests two games. (c) The probability of success when Algorithm 2 returns three games

8. Conclusion

Technology has become increasingly important in education, but it cannot replace the role of teachers in classrooms. Game-based learning has emerged as a new learning method to motivate students and create an active learning environment. However, finding the most relevant games to support a specific subject can be a

challenge for teachers due to the vast number of games available. This research proposes a recommendation method for teachers to choose the most suitable games for their students, with a focus on high school physics curriculum. The recommended technique, based on tensor completion, shows promise even with a small amount of collected data, and could achieve high performance with enough data. This study fills a gap in the literature by suggesting a recommendation method for game-based learning.

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PhD Research Papers

Games as Socio-Technical Systems: Interdisciplinary Infrastructure for a Pedagogy of Play

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Abstract: In the search for a comprehensive framework to structure and instrumentalize a Pedagogy of Play, the present article explores the ludic phenomena from an interdisciplinary perspective, integrating relevant knowledge from multiple sources and complementary epistemologies. As a result, a socio-technical framework of play and games is built, described and exemplified across different cases, over a continuous territory that performs in terms of multiple scales and complexities. The overall intention is not to normalize games, but to integrate more and diverse playful interactions within our everyday lives; not only within basic education but across academic and professional life: an exertion driven by a genuine search to learn from each other and supported by a versatile set of tools. By approaching games as the tangible materialization of play, therefore delegating the material embodiment of whatever comes out of our creativity, to an active learning practice inspired by our curiosity, and that of whom we collaborate with. To conclude, the article discusses and reflects upon the political and aesthetic implications of the presented framework, highlighting the importance of attitudes and narratives that complement conventional study programs by suggesting new ways to approach pre-identified, yet open spaces.

Keywords: Game based learning, Contemporary studies, Interdisciplinarity, Socio-Technical systems

1. An Polysemic Playscape

As an introduction for the socio-technical framework to approach the ludic phenomena from a pedagogical perspective and before we look into what has been written about the subject, we shall begin by looking into play and games from an etymological perspective:

While in English and Portuguese there are two completely different words: play and game, and *jogo* and *brinquedo,* respectively; German, Spanish and French use one word interchangeably. In English, the word game comes from *gamen*, meaning amusement and pleasure; it is related to gambling, to the Swedish word *gamman* (mirth, merriment) and the Icelandic *gaman* (fun). Play on the other hand comes *plæǵa*, which is associated with movement, exercise and festivity, sharing the same root with the word applause.

The Portuguese word *brinquedo* means game and comes from *vinculum* which means connection. *Jogo* comes from the Latin root *iocus* that is also present in the words joke and jewelry. It is related to the French word *jeux* and the Spanish *juego*, that can refer either to the game artifact (*jouet* and *juguete,* which means toy) as well as to the action of playing with it (*jouer* and *jugar,* respectively).

In German, as in other Germanic languages (such as Swedish, Danish and Dutch) the base word is *Spiel*, which also means to talk extravagantly. This term has the same performative implication as in English: fair play, to play music, a theater play, etcetera

1.1 Instinctive Play: Games as Imitation of Life

The study of play has been enriched by the fact that it is present not only within human societies, but in other animals as well. Since the end of the XIXth century, Karl Gross (1988) identified in most mammals and other animals like birds, attitudes of self-exhibition, imitation and decoration that he described as conscious self-deceptions related to developing social abilities such as nursing, mating, exploring, hunting and ruling.

As representations of real-life situations, the fun of games remains neither on the fidelity nor accuracy by which players enact their reality, but by the extent by which they can test alternative situations that otherwise would be too boring or too dangerous. By playing, children learn to express their feelings in a balanced way, through lively languages that are especially important in the early stages of their development as social individuals, in which verbal language by itself is inadequate; it is therefore fundamental for the growth and autonomy of any person (Piaget, 1962).

1.2 Transformative Games: Play as Safe Space

As an attitude towards exploration, play lowers the stakes by which players dare to take part in non-conventional situations. By playing we learn about the consequences of our actions and are able to apply those learnings into real life scenarios: from the protective frame of a rollercoaster, to the psychological bubble around children's play, the social contract that enables players to act differently from what they would, was called by Huizinga

(1957), the 'magic circle' of games. It is within this circle of trust that play happens, as players feel safe to express themselves freely. Moreover, since nobody can be forced to play, games enable safe zones, limited to a certain amount of choices, that players define the rules that govern them, responding to their own needs, inclinations, incentives, and motives to act (Vygotsky, 1976, pag. 537). Playing games allows them to make sense of their surroundings, as they explore and discover the playscape along their own desired rhythm, while avoiding the danger of risking too much.

Emancipated play enthusiasts often have more room to experiment and personalize different mediums of choice: art, performance, parody, simulation, dérive and hacktivism become playful strategies by which it is not only possible, but also fascinating to negotiate between conventional and emergent forms of communication (Flanagan, 2009). Trustworthy play involves genuine self-emancipatory experiences that give players the agency to engage in creative dialogue. In search of their freedom, as they acknowledge themselves as actors, not merely subjects, they coordinate and mobilize in a collective struggle to acknowledge their own destiny, forging common identities and a sense of belonging.

1.3 Therapeutic Play: Games as Remedy

Even if the positive influence of digital games on people's well-being is still unclear (Johannes, *et al*, 2021), other playful activities such as sports and laughter have been proved to be healthy as they generate direct and spontaneous stimuli through which players produce endorphins that contribute to their well-being (Louie, Brook and Frates 2016).

Moreover, games designed with explicit therapeutic intentions have been proved to contribute to mental and physical health, as they speak to the unconscious by creating meaningful engagement, evocative relationships and ultimately changing players behavior (Forgeard and Elstein, 2017; Rusch, 2020). These playful dynamics tend to be based on psychological resonance rather than on imposition or force, therefore maintaining positive attitudes that persist beyond the play time, providing an antidote to boredom (Homeyer and Morrison, 2008) and consequently "freeing the mind from the bonds of imitation" (Kandinsky 1947).

1.4 Educational Games: Play as Didactic Experience

By interacting through games, what Fröbel (1895) called ´gifts´, Vygotsky (1976) ´pivots´ and Winnicott (1951)

´transitional objects´, an educational experience is turned into self-learning practices by which players make their own knowledge, learning what they need, at their own pace (Farnè, 2005). As pedagogical devices, games may be directed by intents that relegate the traditional autotelic character of spontaneous play to an strategic objective: generally setting the correct framework to facilitate learning, not as mandatory but rather as open environments for self-directed adventures.

As Italian pedagoge, Roberto Farnè points out, the games we play entail our first experience of political education, as they require us to assume roles, follow rules, experiment with power, transgress limits, manage conflicts and make decisions within the limited space of action that concern any playscape. By playing together, we build formal and informal approaches to local ´policy making´ by which we represent and constitute communities, developing a group identity and a sense of belonging.

The same flexibility that defines children's play enables teachers and learners to interact using custom-made prototypes that require both sides to apply local foundational knowledge into real life situations. Sometimes explicitly, sometimes surreptitiously, games are insightful vehicles to learn about our own behavior and personality, as they allow players to imagine, test and reflect upon their priorities (Fink, 2003).

1.5 Cultural Play: Games as Evidence of Material History

Johan Huizinga (1957) argued that culture itself can be described as an emergent property of play and Roger Caillois (1958) described games as witnesses of the civilizational process, present in every realm of culture. As nobody can be forced to play, the chance that any game might be played relies on its coherence with the political ideology and social norms of the players; therefore, games are inherently related and influenced by the cultural background where they are designed, produced and played. At the same time, the materials and processes used to build each game reveal the cultural conditions in terms of technological dexterity, material availability, as well as visual references and cultural concerns of both the players and the designers (Avedon and Sutton-Smith, 1971; Spanos, 2021).

Since games are perceived as innovative, fun and attractive, they have a fleeting flexibility that makes them a great vehicle to spread into new cultures, transporting cultural elements across borders, while at the same time

keeping their characteristics together. Similarly to games, carnival, festivals and parties are arenas for cultural exchange characterized by spontaneity and absence of reflection, able to penetrate the spiritual structure of people even more than other 'respectable activities', such as politics and arts (Portilla, 1984).

As evidence of the material culture, games tell about the past in a more democratic way than other sources, as Spanos (2021, p.32) points out: "Object-based history is not solely 'written by the winners', as we tend to say for history in general, usually meaning exactly that texts are composed, edited, censored or even erased from records and memory according to the needs and plans of those in power [...] But the material world also keeps visible (and thus studyable) this part of past life, interaction and development that has not been evaluated by the 'winners'".

1.6 Gamification: Play as Bait

Within design research, playful activities such as building modules, clay modeling and collages can be regarded as generative research probes that situate the research subjects within experiential situations in which people tend to disclose creative behaviors and share privileged information that would not be accessible by means of traditional research methods (Sanders and Stappers, 2014).

While games may empower players to resignify their experiences, it is also true that they can be highly addictive and even used for exploitation. It is worth a look at Flusser (1999) notion of playing without being aware of it, as he frames limits, when "seen from the inside, they are taken for granted; seen from the outside, they are man-made".

A similar hunch may be felt while doing taxes, visiting an unknown city or playing games such as Candycrush (King, 2012) that use gamification knowledge to make people feel frustrated and willing to pay to get to the next level. In contemporary words, even if Artificial Intelligence algorithms seem like a breakthrough technology, it is important to question the biases by which games and any other sort of technology reproduce and implement the same violence of their designers and developers (West, et al. 2019).

1.7 Surreal Games: Play as Resistance

In order to question the metaphors of most mainstream games, built on capitalist values such as centralization and supremacism, Trammell (2020) calls to consider a more inclusive and reparative definition of the term by looking beyond the fun side of games and discussing how play has been historically used as a tool of subjugation that justifies objectivation and exploitation. By playing creatively players are able to rethink the metaphors behind games and subvert their rules, opening new means to issue gender, racial, ethnic, language and class inequities; to examine how power and social change is actually orchestrated, transgressively relying upon direct action that engage aesthetical and political matters (Flanagan, 2009).

From the liberation interest of surrealists like Breton and Soupault, to the critical modes of inquiry of play research, games entail an invitation to question the status quo and to experiment other possibilities beyond the conventional, winning or losing outcomes. Borrowing from dreams, children's games and poetic reverie, Jodorowsky (2007) finds games as stratagems for self-discovery, as they break the illusion of logic and recover imagination, breaking free from reality, they unravel the secrets of the human soul that may provide "keys to unlock the door to the unconscious and to release the visual and verbal poetry of collective creativity" (Gooding, 1991, p. 10).

1.8 Recursive Play: Games as Evolving Systems

From a systemic approach, games can be studied as simple artifacts composed of limited numbers of pieces and instructions that can be listed linearly. As formal systems, games are essentially logical structures that can be coded in mathematical language. The most common applications of these are video games, which rely on audiovisual and hyper-textual interactions, mediated by computer algorithms that are constantly evaluating the behavior of the players (Juul, 2001; Salen and Zimmerman, 2004). The same algorithms that limit the players' interaction, *are* in fact the game, as they dictate what can and can't be done within.

However when played, games become complex and inherently nonlinear as they depend on decision-making. From this perspective, it is possible to identify games as the only form of media where the audience has the chance to interact and actually define the outcome. Beyond their anatomy (whatever a game is made of), their emergent properties result from a second order of consequences that may not have been planned by their designers, if not even better from what it was originally expected (Silveira Duarte, 2015). Games as agents are no longer simple toys nor motionless lines of algorithms, but open, sensitive and recursive systems that adapt

to the players' dynamic experience. Evolved along centuries of play, games can be sorted over different lineages of families, types and genres (Klabbers, 2006; Sosa Compeán, 2017)

2. The Socio-Technical Framework of Play and Games

The following section integrates the different perspectives previously addressed, towards an abductive leap into an overlook that combines these ideas into a comprehensive framework to think of play and games as a

continuous territory. As incomplete as this may be and due to the incapacity to draw a normative description of the ludic fenomena, the socio-technical perspective shall be considered as a open model, as it reflects the two fundamental states at the basis of education: on the one side, the sensitive and spontaneous immersion into the chaos of the natural world and on the other side, an intentional and structured reflective assimilation process that leads to significant learnings (Farnè, 2005).

2.1 The Social Dimension of Play

On its social dimension, play can be sorted by the scale of the space where it happens. The categories depicted in table 1 identify the attributes and representative examples of different games along a spectrum that begins at micro scale with local activities (promoted by internal and perceptive attitudes), and extends towards macro experiences (international relations with political and economic implications). These categories are described as follows:

- Perceptual play encompasses mental and physical activities. It is mostly individual, receptive and reflective. Some examples of these are meditative awareness, physical exercise, listening to music and attending parks, movie theaters and art shows.
- Creative play entails the experimental conceptualization, representation, captivation and manipulation of our surroundings. It is exercised, embodied and expressed through singing, storytelling and dancing or by interacting with objects, such as puzzles, toys, paper, pencils and computers.
- Interpersonal play extends the magic circle of games to a social space in which two or more people interact. As well as creative play, it can happen only among people (e.g. role playing, wrestling and racing) and around playful artifacts (as in chess, video games, football and other object mediated games and sports).
- Cultural play relates to playful activities that happen within particular communities, such as children's play within a kindergarten, local myths, rituals and legends (either urban and ancestral tribes) and folkloric celebrations related to holidays and local traditions. It is within this scale that most businesses operate, as companies let their employees play, they may feel more at ease to work, explore and create cool stuff.
- Finally, on its global scale, the magic circle of games can be identified at international scales by looking at sports associations such as FIFA and the Olympics, beauty contests and online gaming networks. Although some authors may argue that play experience decreases as the players become professional), it is also possible to identify play elements beyond the stadiums and off the court, but as strategic attitudes with economic and political implications.

Table 1. Social dimension of play listed from micro to macro experiences

Microplay	Perceptual	Creative	Interpersonal	Cultural	Global	**Macroplay**

2.2 The Technical Dimension of Games

On its technical dimension, we can refer to games as the tangible and coherent representation of play, therefore, sorted from simple conceptual models, to complex technological infrastructure. In relation to Salem and Zimmerman degrees of complexity (2004), Table 2 avoids fixed and chaotic systems as they may not reach out the category of games, and extend their periodic and complex systems' view into five new categories that refer to the intricacy of their technical requirements:

- Conceptual games focus on interpreting, representing and creating new meaning. Some examples of these are solving riddles, drawing, reading, writing poetry and other wordplay such as tongue twisters.

- Corporeal games tend to direct the attention to the players' bodies. Either individual or not, these games involve physical training. Running, wrestling and dancing, as well as most athletic sports can be identified in this category.
- Material games tend to happen around relatively simple objects such as clay, dice, balls, or decks of cards. As they may also be relational, their emphasis relies on the objects, rather than on the relationship with other players. Examples of these are most toys and dolls, collectables and simple computer games.
- Relational games rely on the interaction between players. Multiplayer video games, as well as running an art gallery or working in Diplomacy can be studied as relational games, since gamers, artists and diplomats tend to act on particular domains aside from reality with relative freedom to plan and execute their own strategies.
- Systematic games are structured around replicable processes, methods or programs. These can be played in cyberspace as well as in tangible spaces and social organizations. Examples of these are surfing the web and owning a football team. These are not based on scattered elements, but on the possibility to intervene on the same structures where games operate.

Table 2. Technical dimension of games listed from simple to complex implementations

Simple games	Conceptual	Corporeal	Material	Relational	Systematic	**Complex games**

In order to combine these dimensions into a comprehensive landscape, Table 3 situates different playful activities across a continuum space that visualizes the socio-technical study of play and games. These examples do not aim to impose a quantitative definition of the scales, nor a normative description of the chosen examples, rather than visualizing the diversity of examples. While the instances in the bottom left corner are normally played individually, the examples on the top right corner tend to be the result of collective play, sometimes competitively, but not always.

Table 3: The socio-technical matrix of play and games with representative examples

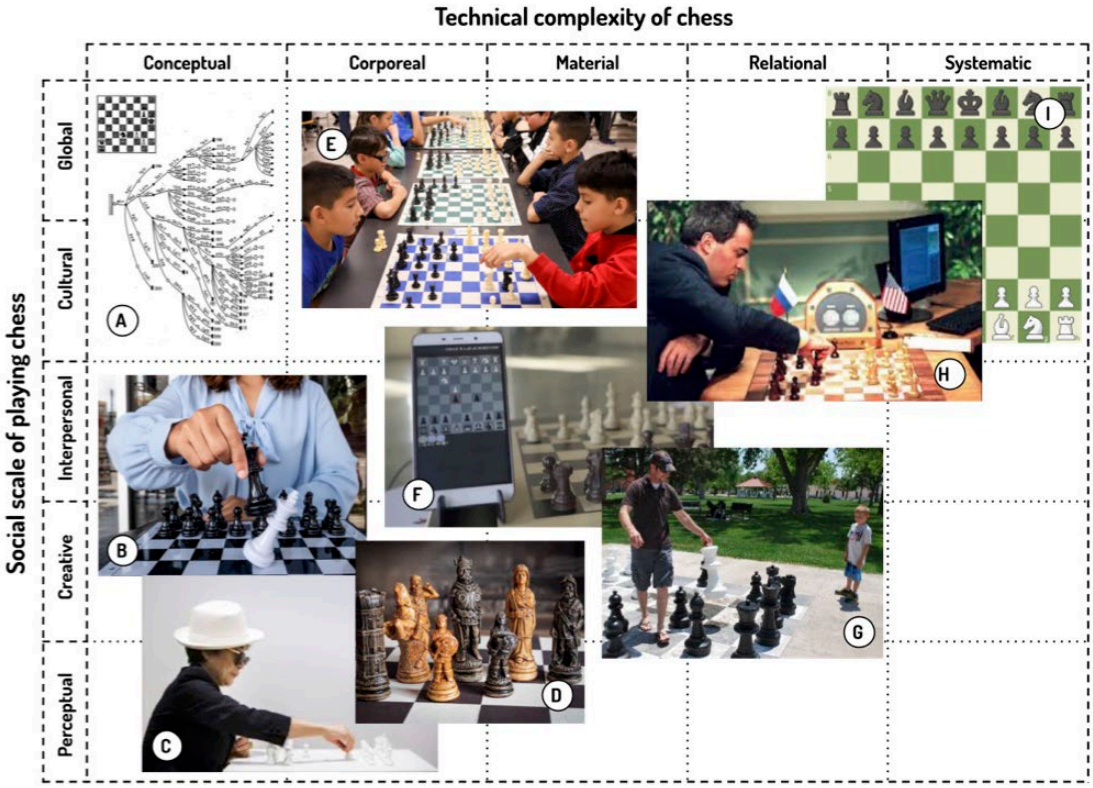
		Technical dimension of games				
		Conceptual	**Corporeal**	**Material**	**Relational**	**Systematic**
	Global	Academia	Miss Universe	TV industry	Diplomacy	MMOs FIFA
Social dimension of play	**Cultural**	Myths Legends	Cosplay	Collecting stamps	Owning an art gallery	Boyscouts
	Interpersonal	Riddles	Wrestling Choir singing	Boardgames	Flirting Dancing	Couchsurfing
	Creative	Poetry Sudoku	Pantomime	Sculpting Solo music	Storytelling	Lego Minecraft
	Perceptual	Reading Meditation	Yoga Gymnastics	Attending an art show	Hanging out	Web surfing

It is worth noting that the experience around a TV is completely different for the producers of the show than for the audience. The socio-technical matrix study shall prevail the perspective of the players, which allows us to understand that for one game, there can be different play experiences: as in Soccer where there are different rules for the team owners as for that of the athletes. Table 4 illustrates the case of playing chess in different playscapes:

- A. Chess is not completely conceptual, only if we think of it as a formal system.

- B. Playing chess with a friend is mostly an interpersonal experience, that is also corporeal. Local contests that gather youngsters to test their strategic abilities.
- C. Yoko Ono's only white chess set for players to realize there is no need to compete.
- D. The work of an artisan who crafts a new set of chess
- E. Local contests that gather youngsters to test their strategic abilities.
- F. The interaction with a smart set that moves automatically while the contestant is abroad (as the technical complexity of the game is high, the interaction of the players with the game claims to be rather simpler).
- G. A father teaching his daughter to play (the complexity relates to keeping the child's attention).
- H. The concentration of Gasparov while playing against IBM's Deep Blue.
- I. A social chess network that matches international players and ranks their performance.

Table 4: The socio-technical study of chess



This example shows an empty space on the perceptual-creative and systematic quadrant. An opportunity for innovators: to develop a new system that is not focused on the interaction with other players, but on single players, for example, by sharing tips and teaching new players how to play chess.

Another way to illustrate a practical application of the play~game continuum, arises when we imagine a teacher using any existing game to teach her students about problem solving. The continuity of this field allows her to frame the exercise within the game (by finding problematic situations within the 8x8 bicolor square board with 32 pieces and 6 different movements of chess) or by looking at opportunities to engage new players, for example, by designing a new set inspired by their favorite characters. From a didactical perspective, both exercises may yield solutions that she can't even imagine on her own; for her, the complexity lays not so much on the technical constraints of the games, but on the possibility to cue the right attitudes and timely feedback for the students, so they can find their own answers and translate them into playable scenarios.

3. Discussion

As gaming becomes online, Walter Benjamin's preoccupation on the shifting nature of art, brings the discussion of games' reproduction from the mechanical era to the digital; as the technical replicability of online games appears to vanish, the discussion about each game's 'soul' shall no longer be laid on the artifact itself,

but on the experiences elicited along their life cycle, from development process to actual play and perish. Game designers must therefore maintain healthy and empathic attitudes to undertake dialogical, critical and ethical relationships over lively and democratic atmospheres where everyone is welcomed to intervene by sharing their experiences and contributing to the common evolution of play.

In accordance with Simon Nicholson (1972), a pedagogy of play cannot be complete if it does not ensure equitable access to self-determination, nor if it overlooks the privilege of participating in crafting other players' experiences. In order to spark collective action, to coordinate political deliberation of everyday life, to take into account the difference and complementary, creative dialogue between players and designers has to be acknowledged as an opportunity to enable intrinsic cooperation, as a genuine search to enjoy each other.

While games do limit the span of play, they also expand the detail by which we can create and amplify fictional universes that liberate ourselves from the tediousness of normality, opening further research opportunities to integrate play into conventional spaces, such as education, but also in tax collection and urban planning, suggesting alternative means for acknowledging the world as open playscapes, allowing players to increase the extent of their agency as they learn about their surroundings by trial and error.

From children to adults, the games we play are key to forging our identity and the reasons why we play may be at the core of our own destiny. In the words of the father of logical positivism and the Vienna Circle: "If we wish to find a meaning in [life] we must seek for activities which carry their own purpose and value within them, independently of any extraneous goals; activities, therefore, which are not work, in the philosophical sense of the word. If such activities exist, then in them the seemingly divided is reconciled, means and end, action and consequence are fused into one, we have then found ends-in-themselves which are more than mere end-points of acting and resting-points of existence, and it is these alone that can take over the role of a true content to life." (Schlick, 1927, pag. 114).

4. Conclusions

When seeing games as part of a cultural environment, Salem and Zimmerman (2004) noted that the boundaries between the playscape and everyday life may be blurred; either by designers who want to control the delivery of the story behind their games or by teachers in the search for cognitive adventures, looking to motivate their students to imagine new forms of being.

In contrast with these ideas, contemporary societies have lost their inclination towards play, focusing most attention to deal with the –real or imagined– threat of the status quo. By relegating social creativity to what Von Borries (2019) described as 'survival design', a state of emergency is normalized, justifying exceptional measures that prevent genuine improvements, since most efforts are targeted to avoid the catastrophe by focusing on the necessity, not on the possibilities. As a result anxiety, submission and other social injustices are legitimized.

Given current circumstances of crisis, misinformation and unsustainable industrial development, it becomes important to highlight the need for clearly stating the intentions behind play. From intention, concept, and materialization, to testing and implementation, the aesthetics of play transcend conventional narratives that focus on the tension between the object and its passive perception. On the other hand, games may be the right cue to enable playful interactions, which may be regarded in the terms of Roberto Farnè, as a meaningful long-life education.

Moreover, as we live in overproduced contexts, where material and symbolic richness is unevenly distributed and continuously degrading (as it becomes normalized and fetishized), play may be issued to recycle heirloom metaphors. In the search for more and diverse significant learning experiences, games implement people's

agency as they inspire new narratives to interpret and interact within our everyday lives, transforming our surroundings into better *possible* places.

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Using RPG-Based Learning Environment to Increase Engagement and Motivation for Learning Higher Mathematics

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Abstract: Although game-based learning has been introduced in various fields, there appears to be a lack of engaging computer games that incorporate higher maths learning (Anagnostopoulou, 2021). This paper presents an exploration of how fantasy-based narrative and storytelling, through role-playing and game mechanics, can be used to increase engagement and motivation for learning higher mathematics in a role-playing game (RPG) based learning environment. As part of this research, the project developed an RPG with incorporated mathematical techniques. Players/learners access the fictional world, controlling in-game characters. Learning evolves via a storyline and six mechanics, progressively building knowledge of derivatives using puzzles with shapes, which gradually fade to the abstract notion of mathematical functions. An experiment was conducted to test the research hypothesis that an RPG based around a quest structure with concreteness fading can enable students to get a better understanding of higher mathematics in the area of differentiation without impeding their entertainment. Participants were recruited from various backgrounds and levels of mathematical knowledge and gaming experience. Data was collected through observations, interviews and two questionnaires: one to be completed before playing the game and the other after. This paper is mainly focused on the qualitative outcomes of the research. The results suggest that the method is effective, with serious learning taking place. The participants reported that they had found the game to be fun and a useful way to learn maths. Moreover, it is revealed that a PRG-based learning environment can increase engagement and motivation for learning higher maths, without invalidating entertainment. The findings have implications for the design, implementation, and evaluation of game-based learning environments for higher mathematics. The paper concludes that this approach has the potential to provide a more immersive, engaging learning experience and increase motivation for learning. Finally, recommendations on how to improve the current game as well as more bold and optimistic ideas for enhanced immersive game builds are suggested.

Keywords: Higher level maths, Game-based learning, Immersive games, Mathematics games, Interactive player experience, KS3 to KS5 maths

1. Introduction

Research demonstrates that game-based learning (GBL) is a valid and effective contemporary method that can replace traditional learning, with various advantages, such as engagement, motivation, fun, immediate feedback, causality, experiential learning, etc. (Steinkuehler, 2004; Tang et al, 2007; Wagner, 2008; Trybus, 2014; Anagnostopoulou, 2017).

This study is using digital game-based learning (DGBL) differentiating the scope into two distinct approaches. Most of educational games are built under the first approach, which uses a 'play, to learn (P2L)' style and involves games that have been designed to teach a topic; the emphasis is on learning the topic first, in a fun way as a secondary objective. In these games, the player automatically realises that the goal is to learn the educational topic included. Prensky's (2001) six structural game elements for learning are primarily related to the educational content of the game. Rules, goals and objectives, outcomes and feedback, competition and challenge refer to the learning topic, whereas interaction is limited and the storyline partial, narrow, or even non-existent.

However, the second approach, 'learn, to play (L2P)' is exactly the opposite, where fun precedes the educational process. Such games are designed to employ whichever technique is required to achieve the goals of the game; while, learning a topic, skills, or acquire general knowledge are just derivative. Mitchell and Smith (2004, p. 49) refer to this design approach, as 'Edugaming', when applied to DGBL. In these games, the educational content is intrinsically integrated into the gaming experience in a way that there is no obvious barrier between fun and learning (Fabricatore, 2000; Mitchell and Smith, 2004).

Various educational games of L2P style have been created across a range of genres. However, Anagnostopoulou (2021), exploring a wide range of the maths games available, identified a gap where there was no highly interactive game available, such as role-playing games (RPGs), with high maths level content, in the range of KS4-KS5 of the UK curriculum. To address this uncovered area, research was contacted to identify ways of intrinsically include high level maths in a game of high player experience. A role-playing game (RPG) was designed, incorporating higher maths in a way that successful learning takes place without impeding the fun aspect.

The game was tested, and the present paper is mainly focused on the qualitative findings of the research.

2. Intrinsically Incorporated Learning in a Fantasy-Based Narrative

Design-based research (DBR) is an established methodology in the field of educational games. It provides a framework for understanding the complex interactions between design, play, and learning. DBR is increasingly being used to inform the design and evaluation of educational games, as well as to build an understanding of the impact of game design on learning and motivation. In DBR, the design of educational games is based on a combination of theory, empirical data, and iterative design cycles. During the design process, designers work closely with players and educators to identify goals, develop game mechanics, design game elements, and evaluate the educational impact of their designs. Through this process, designers gain insight into how players interact with the game's educational content and how these interactions affect learning outcomes. As a result, DBR has become an important tool for understanding the complexities of educational game design (Barab and Squire, 2004).

An RPG setting was chosen as is considered ideal for educational games due to the quality of immersion it offers (Johnson et al., 2015) and well as its narrative factor, which according to Barab and Squire (2004) is a way of coherence of DBR in game systems, as it provides description and guidance for the content, and gradual unfolding of the design.

The present research design followed the six iterative phases of DBR processes as outlined by Easterday et al. (2014) "in which designers: focus the problem, understand the problem, define goals, conceive the outline of a solution, build the solution, and test the solution", but tailored to game-based learning by using elements of Room2Educ8 framework (Fotaris and Mastoras, 2022) (Figure 1).

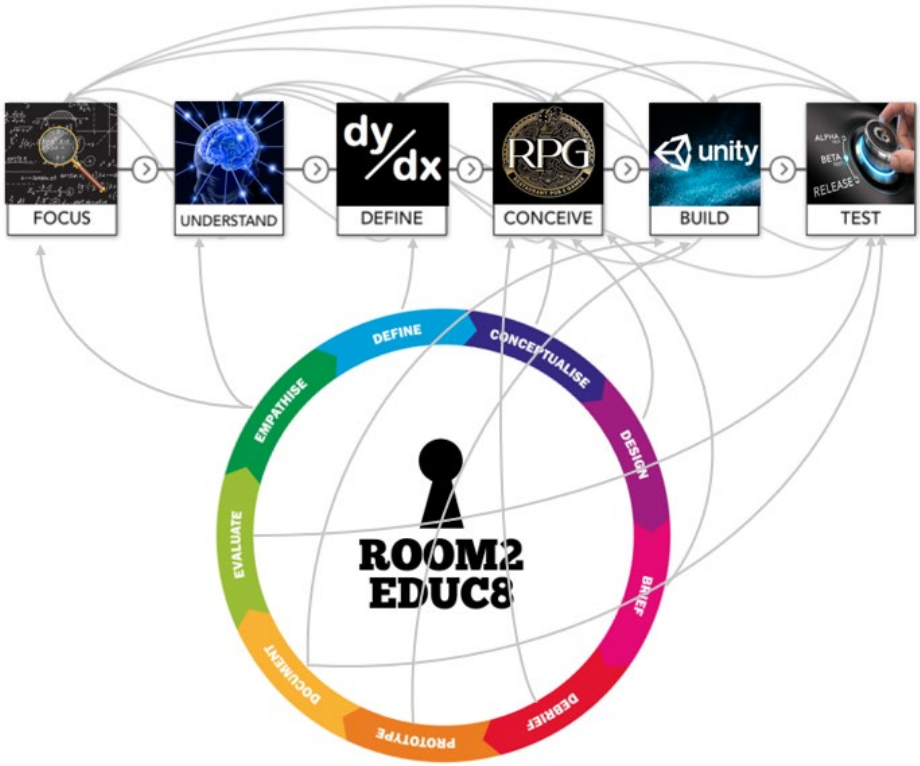

Figure 1: The six iterative phases of the design process: tailored to Room2Educ8 (adapted from Easterday et al., 2014 and Fotaris and Mastoras, 2022)

The six design phases were carried out iteratively and were applied as follows:

Focus: The game specifically targets adult learners with diverse mathematical backgrounds and varying levels of gaming experience, as well as higher education stakeholders by being designed in a way that allows for seamless integration into lessons.

Understand: A thorough literature review was conducted concerning the identified gap in mathematics games, using a diverse range of empirical methods and extensive analysis of secondary sources. Existing solutions in

DGBL within similar or related disciplines, revealing the immense appreciation learners have for immersive games.

Define: The focal point of the mathematical topic and the learning objectives centre in KS5 calculus. By the end of the learning experience, the learners are expected to demonstrate an understanding of the fundamental rules of differentiation, and effectively calculate polynomial, trigonometric and exponential derivatives, as well as use the addition law of differentiation.

Conceive: A RPG environment with a captivating fantasy setting was conceived, creating a fictional virtual world map to immerse players in an engaging experience. To ensure an optimal learning environment, various aspects were carefully considered, including virtual world modelling, narrative development, quest line design, user interface, and seamless integration of mathematical concepts into the game mechanics. The core narrative was thoughtfully organised into a series of events, allowing players to follow a linear quest structure, with a strong focus on fostering motivation through challenge, curiosity, control, and fantasy content, as described in intrinsic motivation of learning theories (Malone and Lepper, 1987). The mathematical content was incorporated into activities designed to maintain a delicate balance between challenging learners and avoiding dullness, ensuring they remained in an optimal learning zone where neither frustration nor monotony prevailed. The learning content design was based on concreteness fading theory (Fyfe et al., 2014). The mathematical concepts were intrinsically incorporated into game mechanics through a fading process of gradual chunking of information, which facilitated comprehension and learning. Derivatives started with a shape representation of the differentiation rules smoothly progressing to abstract functions, in six steps (Anagnostopoulou, 2022). Direct feedback from game mechanics enabled learners to monitor and review their progress throughout the game.

Build: For the practical implementation of the RPG prototype, Unity engine was used as the development platform. During the entire process, detailed documentation was maintained for each stage, which proved instrumental for refining areas of the project and identifying revision requirements.

Test: During the testing phase, the effectiveness of the solution is evaluated. Successive versions of the design were used iteratively. Along with testing in the development stage, Alpha and Beta pilot tests were also implemented to obtain valuable feedback regarding the design's success. The results informed the main testing, which in turn served as a means for determining whether the design has successfully attained its goals and objectives regarding the learning outcomes. Extensive documentation was also carried out throughout the entire testing phase.

2.1 Research Questions

The research questions and hypothesis concerning the qualitative analysis of the results are as follows:

Research questions

RQ1. What is the impact of a RPG-based learning environment on engagement and motivation for learning higher maths?

RQ2. How can higher level maths be included in RPGs without impeding the fun?

Research hypothesis

An RPG based around a quest structure with concreteness fading techniques will engage and motivate students to get a better understanding of higher mathematics in the area of differentiation, without impeding their fun.

3. Methodology

To test the research hypothesis an RPG with incorporated mathematical techniques, named *The Red Circle*, was designed, following the DBR process described above, and developed in Unity engine by one developer and one designer. Players can access the fictional world, controlling in-game characters to complete tasks related to the storyline. Screenshots of the game are shown in Figure 2.

An experiment was conducted with a sample of 148 participants of age range 18-60 years old. The majority of the participants were students of the University of Sussex, which was the main venue of the conducted research. The background of the participants was a mixture of low, medium, and high maths prior knowledge as well as low, medium, and high prior gaming experience.

Figure 2: Screenshots of *The Red Circle* game

The participants were asked to a) complete a pre-questionnaire, b) play the game and finally, c) complete a post-questionnaire. Concerning the qualitative part of the research, the questionnaires were designed to provide feedback regarding the participants' experience, preference of the game mechanics as well, open questions for positive and negative feedback, and resemblance of The Red Circle to any other game. The responses in the two questionnaires were completely anonymous, and aliases were used to match the pre to post-replies. Observations of the gameplay and interviews were also conducted to a selection of the sample to further inform of aspects that could not be identified via the questionnaires. The gameplay time was also recorded. Data was then collected and analysed.

4. Results

This paper reports on the qualitative results of the research. However, a short mention of the main quantitative outcomes is included, as the primary findings of this research pertain to the effectiveness of the game in improving mathematics learning.

4.1 Learning

The game seems to have achieved its goal of teaching the basic rules of derivatives in a fun way. In the full quantitative analysis, Anagnostopoulou (2023) reports that there was a statistically significant increase in maths scores after playing the game, particularly for the players with low prior maths knowledge.

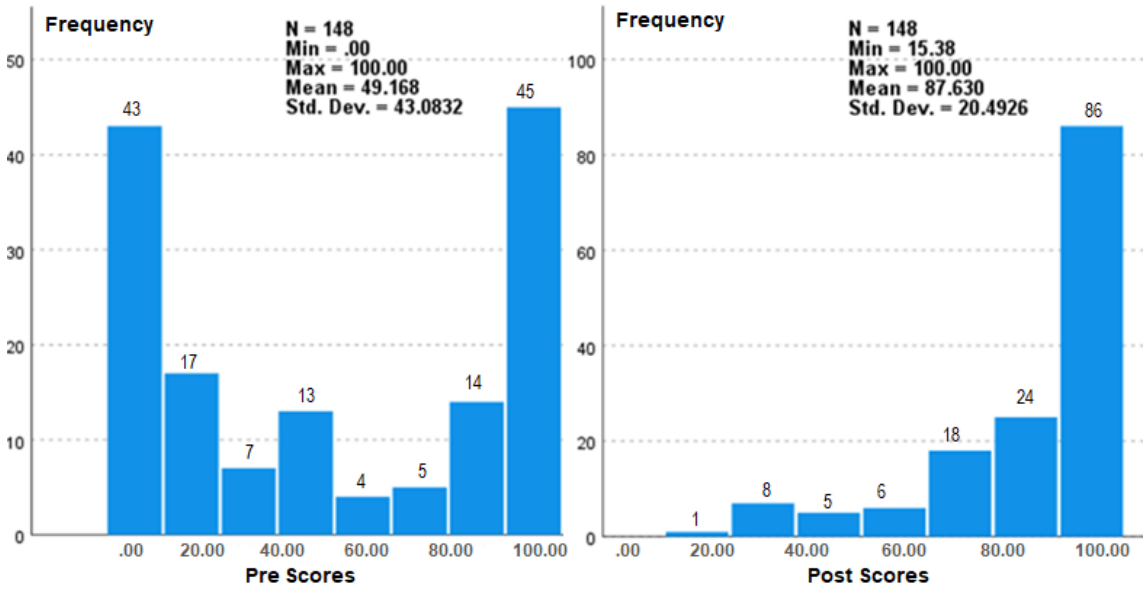

Figure 3: Pre vs. Post Scores

As seen in Figure 3, the mean value of the scores of the participants before playing the game was 49.17% with a dispersion of 43.083% which indicates that the results were highly spread out. However, after playing the game the mean was considerably increased to 87.63%, while the variability was halved. The minimum value was shifted from 0% to 15.38% corresponding to only one person from the initial 43. The mode of 100% corresponds to 86 subjects from 43 of the Pre scores. The histogram curve has been shifted towards the greater score values. This result indicates that engaging in gameplay led to a substantial enhancement of participants' mathematical knowledge. As anticipated, participants with a high mathematics background demonstrated a slight increase in their scores, affirming that the gameplay did not hinder or disrupt their existing knowledge. The group with medium prior maths knowledge experienced a notable improvement in their scores, and their feedback highlighted that the game served as an enjoyable avenue for revisiting and recalling previously acquired knowledge. However, the most intriguing result was observed among participants with low or no prior maths knowledge. The increase in their post-test scores was significant, with none of them scoring zero marks, and over half of the sample achieving full marks in the post-test.

Participants stated that the explanation of differentiation was clear and easy to follow in every step of the process, progression was well paced and the more they advanced in the game, the more they learned about the rules of derivatives. The mini games' levels were challenging enough to make progress and the gradual evolution of the puzzles allowed for better understanding of the maths concepts. Each quest had a specific goal in mind, and they could quickly learn how to complete the tasks and differentiate equations by following the hints presented. The repetitive nature of the questions consolidated knowledge and allowed to quickly recall the answers to the derivatives previously encountered in the game. Players with higher maths knowledge were surprised with the shape representation of derivatives; those that had taken maths a long time ago were happy to see that they were reminded of skills they have forgotten; and those of lower maths skills felt satisfied that they managed to learn maths in a pleasant way. Many participants recommended using such a game instead of a typical class lesson, since it is both enjoyable as well as achieves its learning goals.

4.2 Immersion and Flow

The majority of the players found the game to be immersive. They reported that the beautiful visuals, intriguing storyline, intricate world-building, and the familiarity with the memes used 'hooked' them; even the music was adding to the atmosphere of the game. Intrinsically incorporated maths in direct related to the quest and storyline was also appreciated, as it the mathematical content did not interrupt the flow. The mechanics were consistently themed between different activities and differentiation worked well as a mechanic.

4.3 Engagement and Motivation

Participants testified that overall, they had a pleasant experience playing the game. The environment was built with a comic tone, making the activity amusing. The interactions with the NPCs were entertaining due to the

dialogues having been made intuitively, with the use of relatable memes. The storyline was easy to follow, and the open world exploring was exciting. The combat was engaging, with a good level of complexity progress. The puzzles were challenging, but enjoyable once the players got the hang of them.

They also found the game motivating, particularly those with low mathematics background and low playing experience. Some stated that although they don't play games in general, they are willing to start, following their experience with *the Red Circle* game. They were interested to find out what is next on the story, and they would like to play again to explore the world more. The math puzzle aspect of the game felt a bit frustrated in the beginning for those whose maths is not their strong point, but if felt satisfying when they learnt the mechanics and could solve the puzzles. This motivated them to repeat the quests, just to prove that they can do maths. Some liked the fight feature of the game, because even if it was hard to get the mechanism, causing them to die again and again, they were excited when they were able to kill the enemies in the end. Many referred to the story and quest lines stating that they were looking forward to all the quests there are to do and asked for the follow up.

4.4 Features and Design

One of the comments stating: *"I've seen AAA games that don't flow as well as the Rec Circle. For only a 2-person game build the quality is amazing."* was a particularly gratifying one, as the term 'AAA games' refers to high-budget, high-profile games in the game industry. The design and features of *the Red Circle* game were greatly appreciated by the players. They mentioned that the graphics were beautiful and captivating, the world map was well designed, and the gameplay run smoothly as intended. The majority approved the movement by clicking on the terrain as this way provides a fast-learning curve regarding navigation. The fading of UI elements when the cursor hovered over them was a nice feature, making clicking and walking easier. The storyline was described as gripping and interesting. The objectives were found to be clear, and the players could always tell exactly where they had to go and what they had to do. The game was easy to get started and there were plenty of activities with accompanying background music and sound effects. The players liked the variety of NPCs, each one of different personality along with funny dialogues. The combat feature was well built at this stage, and there was a variety of enemies to fight. The mechanics were well explained and the puzzles quite challenging; it was appreciated how they were all consistent with the game's theme.

4.5 Bugs, Challenges, and Suggestions

There was a lot of feedback on what could have been done better according to the participants perception, which although came from few participants, informs of how to improve the game. The players' comments mainly fall into the category of what is known as 'victim of own success'. The RPG design and graphics resembled a complete game like the ones released in market, developed by companies. Hence, the participants viewed it as such, expecting more of the game, without considering the limitations of this research.

Although the game runs smoothly in general terms, three main bugs were reported by the minority of the players that were found annoying, however did not impede the progress of the game.

These refer to a) a small bug that does not impede gameplay that involves a glitch on a part of the terrain which caused the motion of the player to slow down when walking over it, due of a slight textural difference in the terrain, b) a small bug where the player stuck in a building for reason that could not be identified in the given developing time; the issue was overcome by the implementation of an 'Unstuck' button, and c) a bug that was discovered during the main testing by some experienced players. The games bugged when the key 'F' was used to interact with a certain mechanics of game, instead of the normal mouse right click. It must be noted that experienced players were able to encounter this error, due to the fact that in many games 'F' is often used to interact with the world. This bug was not identified during the pilot tests, but it is easy to fix.

Navigating around in a 3D environment can be a difficult and tedious task, especially for those unfamiliar with the environment. These difficulties involve controlling the character to go around objects, sometimes passing through textures, which would lead to incorrect positions and sometimes colliding with obstacles. The path-finding system needs tweaking to better detect obstacles and plot an appropriate route for the character. Additionally, the players could not pinpoint the exact location of the character on the map as only an approximated position is shown.

Many participants found the game short and stated that they wish they had more time to play, as there was still a lot more to explore. They recommended more stories and dialogues to keep the game interesting and

engaging; use of the rest of the world map for more activities than just scenery; more practice levels; a 'Save' option, so they can resume and continue playing later.

Concerning combat mechanics, some of the experienced gamers asked for a more challenging fight with a variety of skills to use, like use of a sword and block mechanics. They did not like the fact that dying brought no consequence to the player inventory or gameplay and stated that dying is more of a nuisance than something they would want to avoid.

Some participants with high mathematical level background did not like the way that derivatives were initially explained with the use of shapes. They commented that this method of teaching derivative can be confusing to newcomers in the topic. However, no such comment of difficulty was referred by players with low mathematical background.

The players generally liked the high number of NPCs in the game, but they wish they had more dialogues instead or repeating the same meme or joke. They also requested more variety in the quests.

4.6 Timings

The total time of completion varied according to the players' maths and gaming background. The mean time of gameplay of the low age range group, which was mainly university students, was between 40-60 mins, which makes the game suitable in class during a lesson session. Longer playtime involved exploration of the map and interactions with non-player characters (NPCs).

The learning curve of the RPG's user interface, map navigation and interaction with the world was observed to be about 15-20 mins for new players and 3-5 mins for experienced players, five of which who offered to play the game again were observed to have significantly reduced their learning curve to 5-10 mins. This is expected as learning through RPGs requires more gameplay time wherein the player would repeat parts of the game and learn by trial and error, in fact transforming a simple participation to a dynamic activity incorporated to gamers' everyday lives (Herodotou, 2009).

Players with prior math knowledge were observed to be faster in the mechanics with the abstract notation of functions, while their performance in the puzzles shapes was similar to the players with no mathematical background.

4.7 Collaboration Between Players

Many players were playing in collaboration with others, on different computers but next to each other. This practice was encouraged as it marginally simulates a multiplayer environment and can give an idea of the contribution of the social aspect that this game does not address.

Collaborating players were observed to have more fun and be more immersed, discussing with each other, explaining the story, prompting each other to activities outside the quest line, such as exploring other areas of the map or even play with the assets. These players were the ones that talked to many NPCs, laughing at their memes and joke lines.

When they were encountered obstacles, such as difficulties in understanding the minigames, or lost in navigation, or use their UI, they were asking each other for help. in Sometimes they were even competing for who is going to solve the puzzles faster.

5. Conclusion

This paper presented the qualitative results of a study conducted to investigate ways of incorporating higher level mathematics in immersive digital games, without inhibiting players' fun. From the above presented results, it can be concluded that the game was successful in the teaching of differentiation in an enjoyable way. Participants' feedback indicates that an immersive RPG with a fantasy setting and storyline can increase engagement and motivation, thus enforcing the research hypothesis and questions. The mathematical content can be successfully delivered, presented in chunks of a gradual fading process. Mathematical tasks can blend in the quest structure of the storyline, taking advantage of RPG features, such as exploration, crafting, gathering items, fight enemies, etc.

5.1 Limitations

It is well-known that the development of a proper RPG game requires a great amount of investment with respect to funding, workforce as well as time (Castronova, 2007). This study is a part of a PhD thesis in

progress, therefore limited by time and resources. The game was built by only one developer and one designer. Moreover, the limited participation testing time did not allow including the original eight mechanics as set out in the initial plan.

5.2 Future Research

Apart from the immediate fixes regarding game functionality, such as the bugs identified, the short-term plans of the researcher include testing the effectiveness of learning via the game against a control group which will be taught the same topic under a normal class setting. Furthermore, the researcher intends to develop mechanics in order to fade in an eight-step process, as was originally planned. This would result in better consolidation of knowledge. The game can be further expanded to make use of the whole terrain already built for this purpose, with an extended and improved storyline to be more engaging. In this way the playtime will be increase, therefore, a function to save progress should be added, so that the player can return to the game later.

Longer term aspirations involve expanding the maths content, to include mechanics for further differentiation rules, such as the product, quotient and chain rules of differentiation or even explore how to incorporate different maths topics, like trigonometry. An initial idea involves using a 'trigonometric clock' to measure time by means of the trigonometric circle.

As for higher ambitions, the plans need a group of researchers, designers, and developers to transform this single player game to multiplayer. By using competition, rewards, challenge, and acknowledgement as motivating learning factors, more disciplines can also be introduced, e.g., biology, business, literature, etc. with each following a different path of levelling their knowledge. The various expertise could be used, say, in the mechanics of a group boss fight, similar to the group fights of multiplayer games where the groups need to have a combination of healers, tanks, and damage dealers. Ultimately, the dream is to build the first educational MMORPG (Massive Multiplayer Online Role-Playing Game) which is a difficult task to implement, however it was the inspiration from where the whole idea began.

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SwageXR: Designing Gamified AR Applications for Industrial Training

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Abstract: This paper presents a case study describing the design of SwageXR, an augmented reality (AR) application that gamifies a tubing assembly exercise. The aim of this paper is to contribute to the field of extended reality (XR) applications by providing a case study of a novel design process based on an existing framework by Gilardi et al. Design needs and requirements were gathered using a contextual design approach and qualitative research through interviews with training course instructors as well as a workshop involving them. The contextual design approach involved the PI taking part in the training course as one of the trainees to observe and build understanding of the taught practical content and the context in which the learning happened. This was followed by semi-structured interviews with 4 training instructors, with results indicating preferred course content to digitise, early concepts for gamification, and the storyline of the gamified content with respect to existing training. Using the data and experience gained from the contextual design approach and interviews, a paper prototype of the gamified AR application was developed, and feedback was obtained from the company technical director. The paper prototype and feedback were used as a basis for developing a 3D prototype in VR using ShapesXR. This led to a virtual reality (VR) workshop involving the technical director and training manager of the company where the 3D prototype was demonstrated and discussed. The workshop resulted in the flow of the overall application being refined including the storyline, gamification, training, and challenges. The design process aims to facilitate the development of a coded working prototype for SwageXR, with gamification elements such as score, time-based challenges and leaderboards. An initial experience playtest with course trainees will then be possible to gain insight on engagement levels and trainee attitudes about the initial game experience. The main outcome of this research is a design approach that tries to address the gap outlined by Krauß et al., the approach makes use of rehearsal techniques and virtual reality to provide context for AR application design.

Keywords: Extended realities, Augmented reality, Design process, Industrial training, Gamified learning

1. Introduction

Augmented reality (AR) in education and training is a rapidly developing research area, with potential to change pedagogical approaches of industrial training through experiential learning (Aguayo and Eames, 2023). In particular, the design process for creating engaging AR applications for education and training is important as it can affect how the learning is experienced (Chittaro and Buttussi, 2015) and consequently the effectiveness of trainee engagement in the experience. The importance of the design process for AR training experiences is also emphasised by Liu et al. (2019) comparative work between AR experiences and their physical alternatives.

Gamification within AR experiences positively influences user engagement (Dyulicheva and Glazieva, 2022; Eun, Kim, and Kim 2023; Plecher et al., 2018) and leverages it to deliver learning outcomes (Büttner, Prilla and Röcker, 2020).

Early design processes for industrial training AR serious games focused on purely design elements such as learning goals, storyline, and layout (Woll et al., 2011) before evolving to involve an outline of the development part of the process (Marinakis et al., 2021).

This paper contribution is a case study on the application of the design and development framework developed by Gilardi et al. (2021) on an AR serious game for industrial training. The value of this research is the introduction of techniques such as interaction rehearsal and the use of VR to design AR experiences to elicit feedback and contextualise the application for the stakeholders.

2. Related Work

Creating a serious game that contains elements of immersion has direct pedagogical benefits, such as engagement, and motivation (Chittaro and Buttussi, 2015; Plass, Homer and Kinzer, 2015). As such, AR technology is a good medium to increase immersion when paired with serious games (Dyulicheva and Glazieva, 2022; Eun, Kim, and Kim, 2023; Plecher et al., 2018). Experiential learning allows learners to experience, observe, and critically reflect about the subject matter as well as actively experiment with it (Kolb, 1984; Beard, 2022).

XR experiences facilitate experiential learning as they provide learners with elements that support the stages outlined by Kolb (1984) and provide simulated hands-on experience and experimentation. Designing and developing such experiences is challenging, although differing design approaches have been applied by designers and developers, there is no clear established process for XR design and development (Krauß et al., 2022).

Implementing AR in an industrial setting to provide immediate feedback to the trainee can aid to prevent mislearning (Büttner, Prilla and Röcker, 2020) and help avoiding hazardous situations (Li et al., 2018). The lack of an established process for the design of AR applications can impact negatively on the learners' experience in comparison to identical tasks conducted physically (Liu et al., 2019). As such, understanding how to effectively design such applications is an important area of study.

Tooltips (Keating et al., 2011) and best practices (Dirin and Laine, 2018) for AR design are present in the literature to help designers in the process of creating an AR application, however, they lack a structural approach to the design of the experience. To address this limitation there have been attempts in creating early design frameworks, for instance, the one proposed by Irshad et al. (2015), which lacks clarity on where the stakeholders and potential users fit within the design process. Other frameworks focus more on the software implementation of the AR application such as the one proposed by Bacca Acosta et al. (2019). User-based studies approaches are also detailed within the literature (Gabbard and Swan II, 2008), however, these approaches do not focus on designing for educational applications.

Application design and development is also discussed within the literature, for instance, Woll et al. (2011) design approach is based on deriving learning goals, developing a storyline, and the arrangement of the application screens. The relationship between these elements forms the design of the AR application. Marinakis et al. (2021) initial stages are similar to Woll et al. (2011), however, they are followed by two additional stages, development and evaluation. The design goals of both case studies mentioned focused on motivating (Woll et al., 2011) and encouraging (Marinakis et al., 2021) the learners.

In contrast with Irshad et al. (2015), Woll et al. (2011) and Marinakis et al. (2021), the design and development framework proposed by Gilardi et al. (2021), see figure 1, focuses on education applications, involving stakeholders and potential users through the process. In the pre-design stage not only software requirements are identified, but also learning needs, learning goals, and integration of the output software within the teaching context. Each stage in Gilardi et al. (2021) framework feeds back to earlier stages, facilitating an iterative approach. Unlike Marinakis et al. (2021), where iterations of the design are conducted at the very end of the design and development methodology, or Gabbard and Swan II (2008), where the process is linear, Gilardi et al. (2021) approach allows for iterations to occur earlier on in the design process, thus providing early opportunities to refine the design with users and stakeholders and more chances to go back to previous stages, if additional requirements or changes are identified throughout the design and development process.

3. Methodology

The design and development process for SwageXR followed Gilardi et al. (2021). The three core areas of the framework can be derived as pre-design, design, and development. All areas require cooperation between the researchers, designers, developers, and industry stakeholders (managers, and instructors) as well as the trainees. As this paper focuses on design, we will limit our discussion to the pre-design and design stages, with development and evaluation to follow when these stages are completed.

After obtaining ethical approval, the design needs and requirements of the application were collected for the pre-design stage through a contextual design approach (Holtzblatt and Beyer, 2014) within an industrial training company. Contextual inquiry (Holtzblatt and Beyer, 2014; Drachen, Mirza-Babaei and Nacke, 2018) is the core of contextual design, and in this work, it was applied through the researcher posing as a trainee during a two-day training course at the involved company's training facility. Doing so allowed for observation and direct experience to be gained by the researchers, facilitating understanding of the existing training practices and the training culture at the company.

Semi-structured interviews (Lazar, Feng and Hochheiser, 2017) with four company training instructors were used to build upon the direct experience gained from the researcher's involvement in the course and the observations taken from it.

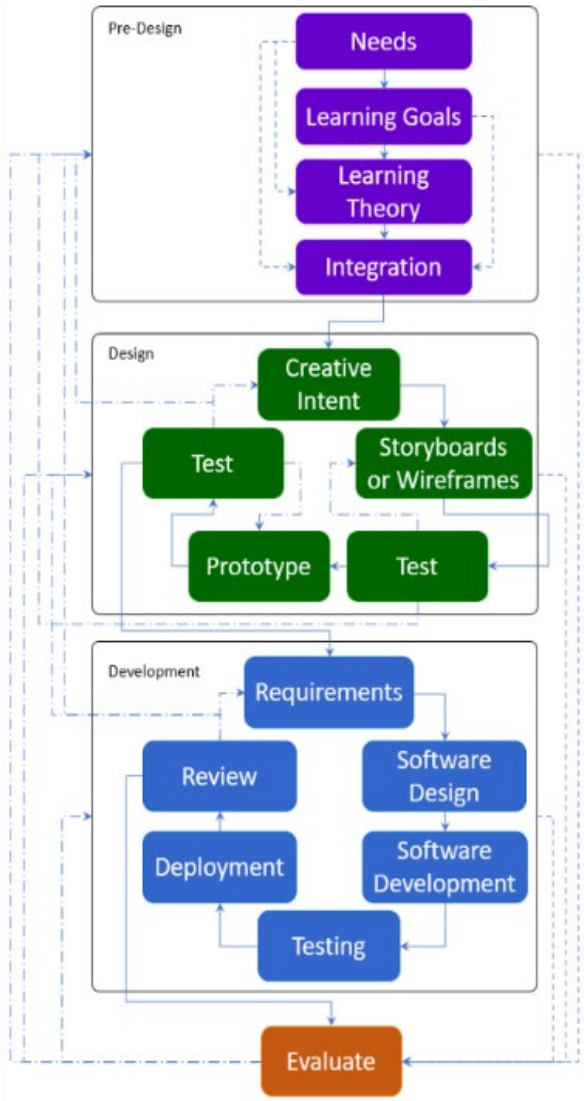

Figure 1: Application design framework Gilardi et al (2021)

Paper prototyping was used to elicit feedback from company technical director, who is responsible for overseeing the training course curriculum and the instructors that deliver it, via an unstructured interview (Lazar, Feng and Hochheiser, 2017). The 'interaction rehearsal' technique was used to help produce the paper prototypes.

A VR low-fidelity prototype of the AR application was designed based off of the paper-based wireframe and used in a workshop to demonstrate the AR application in context via a VR walkthrough. Data obtained from the walkthrough was factored into the design decisions and changes, which will be reflected in the prototype of the gamified AR application.

The techniques mentioned contribute to identifying needs, learning goals, and learning theory of the AR training application and the steps necessary to integrate the existing training course content into a gamified AR scenario.

Although it would have been ideal to involve trainees in each of the methods described in this section, this was not possible at the time due to the company requirements.

4. Design Process

Within this section, the design process focuses into the two parts which map to the design core areas of Gilardi et al.'s (2021) framework, pre-design and design. The application of this framework in this paper can be seen in figure 2. When reference is given to the roles of the research, designer, or developer, it should be noted that for the purpose of this paper, due to resource constraints, the same individual carried out these roles at differing stages of the design process.

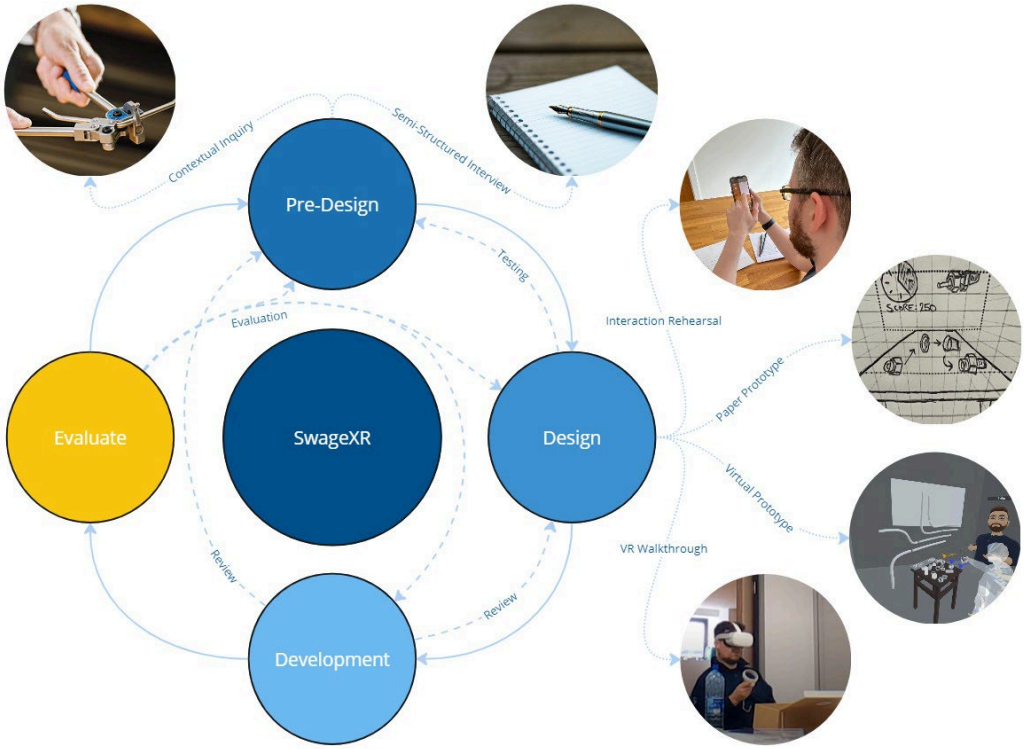

Figure 2: SwageXR design process overview

4.1 Pre-Design

During the pre-design stage the focus is to gather information that contributes to understanding the needs, learning goals, learning theory, and how the AR application can be integrated within the training course.

In order to collect this information the researcher posed as a trainee on one of the company-taught two-day courses. The time spent posing as a trainee allowed for practical and theory-based exercises to be undertaken to develop an understanding of course content and the learning goals of each exercise. During this timeframe the researcher was also able to make in-depth observations about how the training is conducted and the culture within the company.

Observations from the exercises highlighted that a core task was identification and assembly of tube fitting components from four differing manufacturers. The fitting components required to be assembled in the correct orientation and order. The components had subtle differentiating features which is where the difficulty of this task resided. The simplistic nature of the task meant that when performed, it was quickly completed so engagement with the task was short. This was where the company wanted gamification to be introduced.

Semi-structured interviews were conducted with four of the instructors that deliver the course to the trainees supplementing the data collected during the contextual inquiry approach. Before the interviews there was no decision made on what XR technology will be uses for the application. Interview questions aimed at gauging the interviewee's experience with serious games and extended realities, identify what they considered to be some of the core elements of their teaching, and understand what part of the course was seen to be an essential part. During the interviews, discussions emerged around the trainers perceived vision of an ideal serious game and the benefits of it.

Through thematic analysis of the recorded interviews, it was gathered that the trainees needed an increased amount of engagement. Themes emerged on AR as the method of delivering the extended reality experience due to the trainee accessibility to a smartphone during the runtime of the course, and of what content would be considered core for the serious game. During the interviews discussion identified a theme of the spatial representation of how the AR scene could appear in various areas of the room. The insights suggest that there would be many trainees using the AR application at once, so it was important that the trainees did not get in the

way of one another. Opinions of how the scene would appear would be to attach it to a plane such as the desks in front of each trainee.

Gamification options were discussed with the instructors with a theme emerging around real-time competition, in-line with the work of (Li et al., 2022). The discussions with instructors were leaning towards something that would be time-based with the potential to score dependant on progress. To add an additional layer to the real-time competition theme, a gamification idea of having a leaderboard was mentioned to increase the competitive nature of the application. The scope of this leaderboard was suggested to split into three categories for daily, monthly and all-time, the categories allowed for a competitive nature to be discovered by the trainees for not only the current training course, but with previous cohorts as well.

After the thematic analysis was completed the design decision of developing a gamified AR training application about tube fitting was made to address the need to improve engagement with the course and introduce something novel for the trainees. Experiential learning was selected as the pedagogy to help address this need (Liu et al., 2019; Aguayo and Eames, 2023).

After discussion with the course instructors it was agreed that the gamified AR training application will be integrated as a complementary element to the existing course structure when integrated alongside current practices, to facilitate engagement of trainees. Operationally, to access the application during the course, it was also agreed with the instructors and the technical director that a QR code will be visible on the trainee desks for them to scan.

4.2 Design

Based on the information gathered in the pre-design stage, the first design of the AR Serious Game took the form of low-fidelity prototype. At this point, the creative intent was to design a spatial environment that enveloped the training course learning outcomes (tube identification and assembly). Design considerations also involved how to effectively apply gamification to appeal to the training course trainees.

A paper prototype was developed starting with an 'interaction rehearsal' approach, also known as 'acting-out interactions', of the scenario (Gilardi et al., 2016; Dunlop, 2014; Masterclass, 2023) to give an idea of potential user movements and interaction when it came to planning out the scene on paper. Interaction rehearsal is performative interaction design approach that can be employed in the earlier stages of design, where the designer or the potential users physically act out the movements how they believe interactions should occur (Macaulay et al., 2006). Scoping of interactions is beneficial as design elements are made apparent that were not obvious without placing a person in the scenario, an example for AR serious games would be spatial awareness and restrictions and safety issues the user may encounter.

The preliminary scene design concept for the AR training experience was drawn on a 2D equirectangular grid, figure 3 left, before being scanned and loaded on a mobile device to be explored in more depth, figure 3 right. The paper prototype gave early insight into spatial layouts and how the end user may perceive and interact with the elements of the prototype.

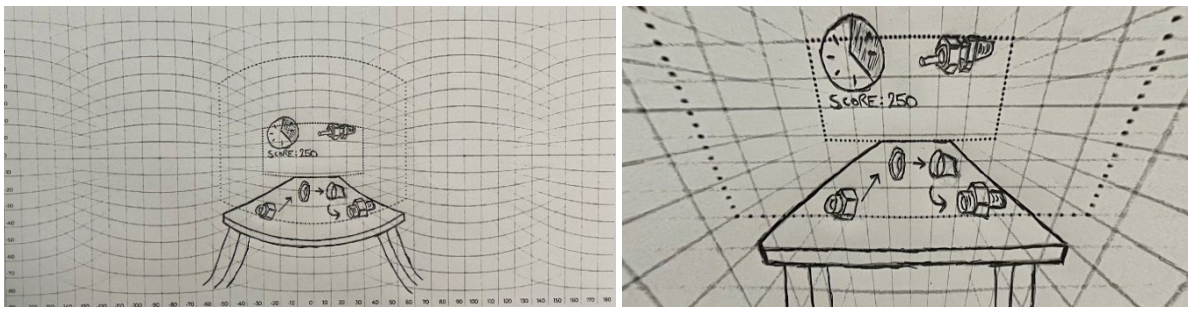

Figure 3: Left, one of the paper prototypes drawn on an equirectangular template; right, same paper prototype applied to a 360 sphere, live version here

Following the paper prototype design, further creative planning was done through storyboarding (Leighfield, 2023) of the gamified AR training application layout (figure 4). Including, a splash screen, main menu, revision section, leaderboards, and the gamified challenge area containing the current paper prototype.

The technical director of the company participated in a feedback session where the application flow was presented, before engaging in a discussion regarding this stage in the design process. Feedback from this session

highlighted the different considerations for interaction with the tubing components within the challenge and revision modes of the application.

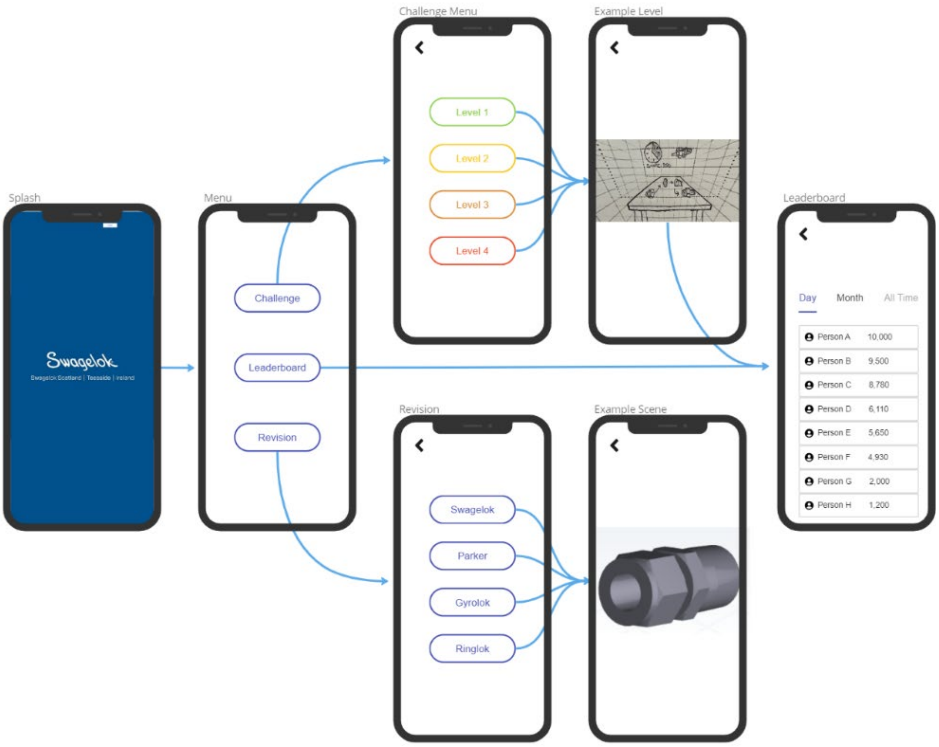

Figure 4: Storyboarding of the gamified AR application during pre-design stage

Highlighted areas included the need for trainees having immediate feedback within the component assembly challenge of the application was outlined, whether their actions are correct or incorrect. Moreover, the application will need to load different components each time it is loaded, to avoid trainees having the same training experience every time the app is used. As a result, a design choice was made to use procedural generation when loading components. Additionally, a new security requirement for the application was defined, with the gamified AR training application only being accessible at the training facility.

Based on the feedback session, a low-fidelity prototype was designed within ShapesXR (Shapes Corp, 2023), a tool to design prototypes within VR, figure 5, this involved creating a spatial environment resembling the space where training will take place, containing a progression of scenes for how a trainee would use the AR serious game. The VR-based prototype allowed for contextualising the AR application. The immersive element of this second prototype was beneficial as it allowed for those involved in its exploration to gain an additional understanding of how the gamified AR training application would function.

The VR workshop included the technical director and two instructors from the company as well as the designer. The workshop demonstrated the gamified AR training application design, utilising the 3D space within VR to convey intended movements and interactions of the user.

Figure 5: Four Screenshots from the VR Walkthrough of the Gamified AR Application. Showing Trainee Using QR Code and Security Code (far left), the Designer Demonstrating Functionality (left), Correct Configuration Feedback (right), and the AR Leaderboard (far right)

Critical information obtained from the workshop involved concerns surrounding how detailed the 3D models of the tube fitting components could be, as subtle detailing on the components was crucial for differentiating them. As a result, it was organised to 3D scan the fitting components to allow for higher quality models used within the AR application. Feedback from the workshop also involved the UI presented for the application and consisted of a reordering of elements on the menu.

4.3 Development

Data collected from the industry stakeholders allowed for the initial coded prototype requirements to be outlined. The development process of the coded prototype is still ongoing and follows an agile workflow (Dybå and Dingsøyr, 2008). The AR application targets both Android and iOS devices to ensure accessibility for trainees, whilst development is done within the Unity Engine using the XR interaction toolkit. When development of the coded prototype is concluded, review of its ability to increase trainee engagement with be analysed with a combination of initial experience playtests and usability tests (Drachen, Mirza-Babaei and Nacke, 2018).

5. Conclusion

This paper contributes to the field of XR application design by providing a case study about the XR design process of Swage XR, which builds on Gilardi et al.'s (2021) design framework. This case study applies Gilardi et al. (2021) to design AR training, adding interaction rehearsal techniques and VR pre-visualization as viable design methods. Such methods provide stakeholders with additional context regarding the final application at the prototyping stage. The additional context elicited further feedback from the company technical director and instructors that was not obtained during discussions around the paper-prototype.

Unlike the design processes of Marinakis et al. (2021) and Woll et al. (2011), the application of contextual design (Holtzblatt and Beyer, 2014) allowed for first-hand experience to be gained, which provided quick information uptake. Obtaining the knowledge about the training this way formed a baseline for understanding the training practices and what was required for the application design. This approach led to an interview process that focused on current training practices before undertaking low-fidelity prototyping.

One of the techniques used in this paper was 'interaction rehearsal', which in some ways is similar to the AR design approach taken by Thompson and Potter (2018), which used 3D printed props to let users' act-out AR interactions. Although similar to Thompson and Potter (2018), the approach taken in this paper did not use 3D props and was limited to the designer. Further exploration will involve using potential users during the interaction rehearsal stage.

Despite interaction rehearsal being limited to the designer, applying it to the AR scenario allowed for recognition of conceptual design issues, and ideas on how to address them. For instance, a recognised issue was that user interactions involving depth required the user to move with their device to reduce distance to objects in the AR scenario, potentially causing fatigue and safety issues. To address this, limiting the space of a user's physical environment to the desk in front of them meant that depth-based interactions could be conducted with more subtle device movement.

Two prototypes were created during the design process, a paper-prototype and a VR prototype. Paper-prototyping is a well-known approach for application design (Chandler et al., 2002; Lumsden and MacLean, 2008). In the field of XR this has been translated into using equirectangular templates to simulate space (Nebeling and Madier, 2019). The benefits of this approach are similar to traditional paper-prototyping, which allows to refine requirements and needs before committing to software prototyping. In terms of virtual prototyping, we took the approach of generating a VR scenario to contextualise the AR application. To the best of our knowledge, we are first to document this approach.

The VR scenario added the benefit of providing better understanding of spatial relationships between the AR application elements for the VR walkthrough participants, which allowed for more specific feedback surrounding AR interactions. The limitation of this approach is the need of VR equipment for the participants, which may not always be available to them.

A limitation of this work is that it did not involve final users (trainees) into the design process, this would have enabled to develop the application using co-design approaches, however, this was not possible to the company requirements.

Future work for this project would be to implement the design into a functioning AR application, which will allow for analytical methods to be applied to measure trainee engagement and learning, thus validating the design correctness.

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Introducing Resource Management Into a Large-Scale Cyber Security Seminar Game: A Case Study

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Abstract: In seminar wargames, participants are asked to resolve problems presented by an umpire, who also adjudicates the outcome of the player decisions. This type of game has been used across a wide range of contexts, including notably in cybersecurity training. Seminar games, however, have been criticized for their lack of rigor. The solutions developed during the game can often be idealized. It is also common for these games to have pre-scripted outcomes. This minimizes the agency of the player and reduces the investment the player can have in the game. This paper focuses on the design and development of a seminar wargame with a novel resource management component. This component expands on the traditional seminar game and addresses some underrepresented training needs. The game was designed using a participatory design framework and the process is clearly described in the paper. The game was then played during a large-scale cybersecurity event by governmental representatives from 18 different countries using a hybrid game system. Data was gathered through a series of observations made during play, interviews with participants, and discussion during a debriefing session. Preliminary results show that the participants and sponsors felt that the game improved the overall quality and utility of the seminar style wargame. While the practical implementation of the game requires refinement, the overall approach is viable for a broad range of contexts in which seminar-style games can be used.

Keywords: Cybersecurity, Training, Participatory design, Game-based learning, Seminar game, Wargame

1. Introduction

The field of cybersecurity is one of continued growth. There is an estimated shortfall of over 3 million jobs worldwide in the sector for 2023 (Blažič, 2021). Attempts to address this shortfall have ranged from the introduction of degree-level courses and summer camps to the use of games in teaching and training (Jin, *et al.* 2018). These initiatives have tended to focus on the technical training of future cybersecurity professionals, utilizing approaches such as capture the flag competitions and cyber ranges to allow technical students to practice in a realistic manner. However, cybersecurity exists across several domains, not just the technical. From the lowest-level employees to the high-level government decision-makers, an understanding of cybersecurity is becoming essential. Unfortunately, the training used for these groups often focuses on old school chalk and talk modalities that can do little to actually change their behaviour.

Traditionally, the games used to train people involved in the strategic decision-making domain have been a form of seminar wargame game. Originally developed by the Rand Corporation in the 1950s, seminar games sit the players around a table and present them with dilemmas. Solutions are described by the participants and the umpire judges their effectiveness. Then the participants are given another dilemma (Perla, 1985). While these games have demonstrated their utility in a range of contexts from predicting future oil values (Bradfield et al., 2005) to the impact of nuclear war (Kahn, 1984), they have also been criticized for their lack of rigor. It is common for these games to have pre-scripted outcomes, reducing player engagement due to the limited agency and potentially reinforcing pre-existing prejudices instead of providing novel solutions. Further, the solutions developed during the game can often be idealized and lack consideration for the practical constraints of real-world cyber warfare, such as limited resources. This has led some experts to derogatorily label these games as BOGSAT's: a Bunch of Guys Sat Around a Table (Caffrey, 2019).

To address this problem, a new cybersecurity training game was designed. This game introduced a resource management component to a hybrid analogue-digital cybersecurity seminar-style wargame aimed at governmental representatives taking part in a large-scale international cybersecurity exercise. By adding resource management, the game introduces the importance of task prioritization when operating with a limited pool of resources amid a simulated series of crises. This was done to increase the realism, as well as players' investment in and engagement with the game.

2. Methodology

2.1 Context of use

The game was designed to be a part of a large-scale (over 1,500 participants) cybersecurity exercise known as Locked Shields. Other parts of the overall exercise would include a technical game using a cyber range. Two other seminar games were also run in parallel, one focusing on the legal aspects of cyber incidents under state

and international law, and the other examining disinformation and how to construct media policy. With the game being part of such a large-scale event, it was essential to get all aspects of the game approved by multiple stakeholders throughout the process.

2.2 Research Design

This study used a participatory design methodology: an inclusive design methodology that seeks to draw experiences from the end user of a product in its creation (Simonsen and Robertson, 2012). A key element of participatory design is that it focuses on the production of an end product, system or artifact. This was especially suited to the purpose of this study as a game had to be produced by the deadline. The other advantage of participatory design is that it encourages buy-in from multiple stakeholders. This makes the approval process for the adoption of the final product more straightforward.

The participants involved in the design process included several experts in the field of cybersecurity policy and strategic decision making from a recognized centre of excellence dedicated to the subject; a player of the seminar game from the previous year's game used at the same event; and an expert in the design of the computer platform used to facilitate the game. The author of the paper acted as a facilitator and game design consultant.

The first step was to conduct an ideation and brainstorming session with key participants. Following this, rapid iterative prototyping was used. This enabled all participants to provide feedback and make suggestions for improvement throughout the process. The game went through eight separate iterations of design, involving five training sessions and three full playtests with players who had no experience with the design, before it was deployed as a final product.

Qualitative data was gathered during both the playtesting and the final deployment of the game based on a combination of observation and interview/discussion with the players. Observations were conducted after every resource management turn during playtesting and after every 10 minutes during the implementation of the game. Observations focused on the game state of the various participants. Notes were made on decisions that were being observed and perceived difficulties being experienced.

Informal interviews were conducted with the playtesting groups to gather ideas for improvements to be made. A semi-structured interview based on the recommended debriefing method for wargames (Van den Hoogen, Lo and Meijer, 2016) was used with players of the final game. Finally, a debrief was held on the day after the final play concluded. Impressions and comments were sought from the participants through an open discussion.

3. Design and Implementation

3.1 Game Concept Outline

Before commencing the design, the seminar game from the previous year was analysed to generate a clear view of the limitations to the game design and understand the audience and context of use for the game. Below is an outline of its gameplay, which became a starting point for the redesigned game.

The game would take 3 hours to play and involve two types of players. These were the white team liaisons (WTLs) and the strategic teams (ST). WTL's were representatives of the country or team who were engaging with the training game. They would travel to the physical location of the exercise and coordinate the play with the strategic teams located back in their home country.

WTL's are trusted agents within the system. This means that they have more information than other players and a responsibility to confidentiality. This is similar to how a dungeon master may work in roleplaying games. They have access to all the information of the setting and adventure (scenario and inject decks containing sequenced in-game events) so that they can advise the strategic team on what roles will be needed. At the same time, they have a responsibility to not spoil the game by giving too much away. Their position as mediators helps to keep the strategic teams on track and provides translation and other skills that allow the game to be internationally playable. The WTL's were involved in all aspects of the game design and testing.

The strategic teams (ST's) were made up of representatives of national governments. These people would be expected to either make decisions or advise political leaders during a cyber security crisis. They could be drawn from the civil service, military, or critical industries. The makeup of the teams would not be known by the designers before gameplay and the identity of the players would be kept confidential throughout the process.

During the game, the WTL would ask the players to imagine their country was undergoing a series of cyber-attacks, narrate the events and posing questions for the ST to discuss and answer. Given that questions used in the game could touch on areas of governments security preparedness for crisis, the answers were highly sensitive. Due to the ST's being located in their home countries, their interactions with the WTL's would take place online using a dedicated software system. This would mean that the game system would have to be simple enough to be used with minimum support from the designers.

3.2 Ideation

The initial brainstorming and ideation meeting took place in late October 2022. The discussion highlighted the disappointment of stakeholders with the previous years' game. It was decided that the new design should act as an add-on to a traditional seminar game rather than replacing it, increasing the value of playing the game and making it more engaging.

Three key issues were identified during the discussion: 1) the lack of player agency and game persistence (each of the decision points was independent from all other decisions), 2) an assumption that the solutions presented by players were to take effect immediately, and 3) strategic decisions being taken in isolation from their operational context. The game design would thus focus on addressing these three core issues.

3.3 Prototyping

Once these key issues and practical constraints were defined, a prototyping session was held in November at Tallinn University's Game Lab. During this session, rapid prototyping was used to address the issues identified in the ideation meeting.

To address the lack of agency, players were given a series of projects that they could choose to start or pause at any time during the game. These projects would be linked to the strategic questions that they had already engaged with in the regular seminar side of the game. To deal with the immediacy issue, a turn-tracking mechanic was introduced, whereby the projects would take several turns to complete. Finally, there needed to be resources that could be used to begin projects. These resources would have to be limited to make the decision of which project to begin meaningful for the player and reflect the limited number of skilled cyber-operatives any government may call on. These three components and their interactions became the core of the gameplay.

The updated game involved two distinct types of questions. Type one were the traditional strategic-level questions typical of seminar games. These would trigger discussion and an answer, but would not trigger the decision to start a project or not. The other type of question was "actionable," meaning it would trigger the creation of a project. If the players ran out of resources but wanted to start a new project, they would have to either pause a current project or wait for a project to reach completion. The core loop of the game is summarized in Figure 1.

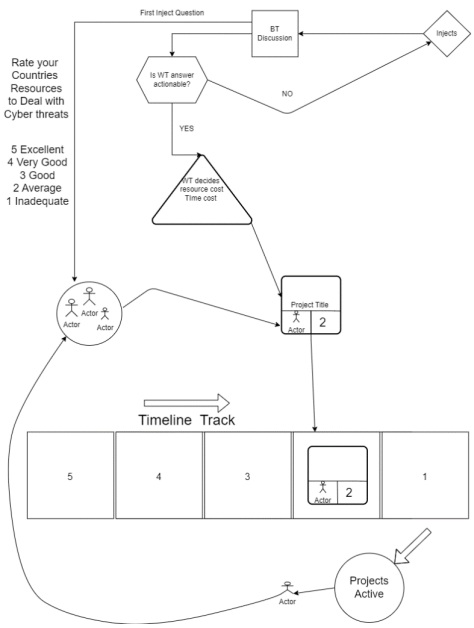

Figure 1: Core gameplay loop

Below is an outline of other major changes introduced into the game across several iterations of prototyping.

Hybrid board game design

Originally, the game was to be computer-based so that everyone could track the progress of projects and see the state of play. After consulting with the commercial supplier of the software used in the event, it was decided that the timeline was too short to implement such as system. However, they would work on rolling it out for the 2024 edition. In the meantime, the 2023 version would be designed as a board game controlled and administered by the WTLs, who would communicate the game information to the ST participants online.

Resources and turn-tracker

Originally, resources were conceived as being between 2 and 10. They would represent the teams that the players had available to address the problems. The decision to deploy the resources or not would be the key decision point in the resource management game. While governments have access to many resources, it was decided to limit them for game purposes to help to create dilemmas for the players to explore. It was also decided early in the design process not to have teams with different specializations, as this would further complicate the game and add to the processing load on the players for a limited educational return.

The allocation of resources to the teams went through several iterations and discussions. Initially, the plan was to ask each strategic team to rate their countries readiness on a scale from 1 (poor) to 5 (excellent); then, two teams would be awarded for each point the country had given. This was changed in part because some countries have historically overemphasized their capabilities, while others may underplay their capabilities in a cultural form of modesty. The next iteration focused on asking players questions drawn from the Cyber Readiness Index (Gomez, 2013), which would focus on specific competencies and result in additional teams being awarded in addition the baseline of three teams. Eventually, it was decided to simplify it still further and give only four teams to each ST. This was done so that the exhaustion of resources would occur faster in the game, forcing decisions to be made and ensuring that not every project could be started.

This decision also affected the turn-tracker on the game board. As the game was originally conceived as being computer-mediated, the timeline for each project was not originally fixed. However, due to the above considerations and practical constraints such as the small size of the game board (A4), the number of turns on the turn tracker timeline was fixed at four.

Project cards

Two different types of project cards were defined: Standard and Mandatory projects. In Mandatory projects, the player had to begin the project no matter what. The initial Mandatory project was conceived as a flu outbreak within the cyber-response teams that may have required staff reallocation for a set number of turns. Standard projects were to be given a cost in number of teams by the WTL and they would also decide how long they felt the project would take to reach completion. During the online training sessions, this was found to be too confusing for the WTL's and led to the collapse of one of the test runs. While the initial system would have provided more flexibility and provided a more tailored experience, it came at the cost of complexity in training and execution.

To resolve this issue, project cards were simplified to being only one team per project and the time to completion being fixed at four turns for both Standard and Mandatory projects. This had a knock-on effect on the resources, as the number of teams would have to be limited to no more than four to prevent the strategic teams from completing every project they were presented with.

Inject cards

In order to compensate for the insufficient amount content in previous years' games (players would often exhaust the content before the three-hour playtime ended), 70 inject cards representing in-game events were designed. During playtesting, it was discovered that this was too much material, and it had to be dramatically cut down for the final game, resulting in 36 inject cards. The cards were printed with key text about the inject and the number in which the card was to be played, as the in-game events were designed to take place sequentially.

Miscellaneous changes

The original game board used for the full playtest is presented in Figure 2. The aesthetics of the game board were subsequently changed to conform with the corporate identity of the larger exercise. The colour and

markings of the board were also changed, and the logos of the exercise were added (the final version will not be shared in this paper).

The original tokens representing the teams were redesigned to stand more upright and be easier to handle. The tokens were designed in Blender and then 3D printed.

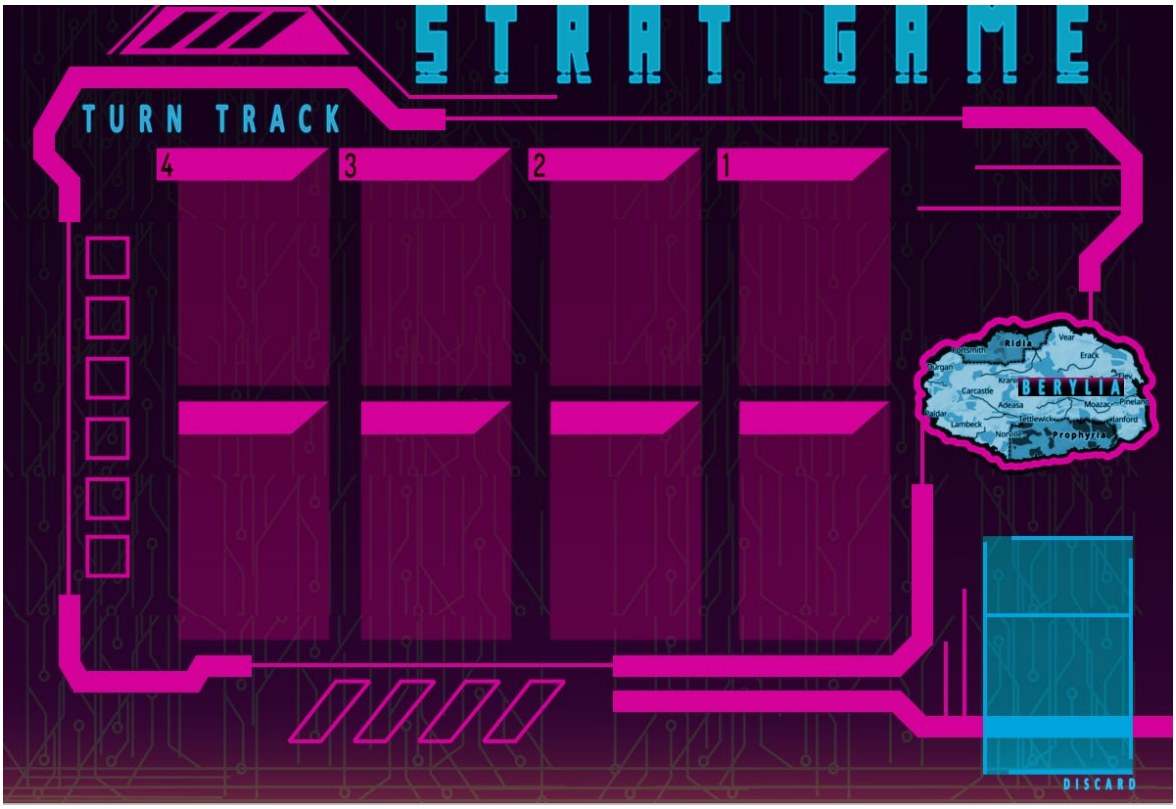

Figure 2: The original game board

3.4 Final Ruleset

The following rules were used in the final version of the game.

Setup phase

- Place one team token (four in total) in the squares on the left-hand side of the board.
- Place the project deck face down to the left of the tokens.
- Reveal the first card.
- If the players decide to send a team to support their ally, place one team token in the country on the far-right hand side of the board.
- Otherwise, place the card on the bottom left-hand square of the game board.

Decision phase

- During the resource management phase, the next project card is revealed.
- If the players wish to begin the project, they must staff it with a team.
- If there are not enough teams available, a team may be pulled from another project.
- A player may decide to staff any project card that is currently available.
- Mandatory projects must be staffed and completed.

Movement phase

- Once all decisions have been made, the movement phase begins.
- Any unstaffed projects cards are moved down to the row beneath their current position.
- Any staffed projects move one step over to the right.
- Any new or restarted projects move up to the active row.

- If a project reaches the end of the active row, the project is complete, and the team returns to the available position.

3.5 Running the Game

The strategic seminar game included representatives from 18 separate countries spread across four continents and one team of industry specialists. Each team had a white team liaison in the game room located in Tallinn in Estonia. The WTL would act as mediator and controller for the pace of the exercise. In addition, they had an open channel of communication to their home countries' team to facilitate the gameplay process. Answers to all the questions were gathered on a dedicated secure server maintained by a company specializing in cybersecurity exercises.

The game was played for 3 hours with full technical support on standby. Given that players were engaged in multiple time zones, the game network was left open for two days to allow teams to continue play. The extra playtime did not include rapid technical support or observation of play, however.

4. Results and Discussion

4.1 Observation

18 out of the 19 WTLs engaged with the resource management game. The one who chose not to engage had not attended the trainings for the system online and even with support given the day before was not comfortable with the system.

An additional team decided to play the game out of sequence and readjusted their deck to suit this new ordering. The game was robust enough to handle these changes, although this did throw off the intended use of the mandatory projects to force the players to have all teams active. The WTL did not report any problems experienced because of this.

The very first decision presented to the players was whether to send a team to aid an ally who was experiencing an attack. All ST's sent a team to aid in the turn: 17 did so when it was initially requested, and the final ST sent the team after almost two hours of play, when several projects at home had been completed. At no point did any players pull their team from supporting their allies. This could be showing the strength of commitment of the nations involved to mutual defense, or it could show that they were not put under sufficient pressure by the events being simulated in their home country. Either way, it is an interesting data point to explore in future iterations.

One of the mandatory events was a call from the prime minister's office asking for a team to be devoted to look into an embarrassing hack. One team decided to ignore this completely and refused to begin the project for one turn until their WTL insisted. The liaison theorized that this was because his strategic team was made up of primarily technical people, who did not see the necessity of the project.

One WTL brought a specific webcam and tripod setup so that they could display the resource management board to the strategic team at all times. This was in line with what had been done during the training sessions for the WTL's. He reported that it made explaining the situation a lot clearer, marking this as a useful approach for future implementation.

Two distinct play styles were observed when dealing with the resource management component. The first could be labelled the conservative style. When playing conservatively, players would always have a team in reserve ready to be deployed should an emergency arise. They would often have a backlog of projects and would decide on the project to begin based on the importance that they assigned them. It was rare for them to begin a project when it was first presented to them; instead, they would wait to see what was happening next before choosing to act. The second, more aggressive style of play, was to have teams working on projects at all times. This form of play emphasized the ability to pull teams out of projects in case of emergencies or mandatory projects. Trace data of actual game play will have to be reviewed to see if one strategy produced better results than the other. In general, the team drawn from the industry played much more aggressively, while those teams who reported having military involvement played much more conservatively. A similar pattern had been observed in playtesting, where the student players (the non-experts) were more aggressive in their approach than the expert team. How much this reflects cultural practices inside the players is uncertain, but would be interesting to investigate further.

One strategic team continued to play even after the time had expired and completed all injects with a full discussion of the relevant information. This took over 8 hours of full play time, showing significant engagement and commitment.

4.2 Interviews and Debrief

Four interviews were conducted with WTL's immediately after the game. All participants expressed a positive view on the value of the game. One interviewee reported that their strategic team spent almost equal time debating the use of resources as they did the strategic questions. This was a surprising finding, as the resource management component is a simple system of binary choices (staff the project or don't staff the project). This highlights that the introduction of resource management increased both the player engagement and raised interesting problems for the player.

The debrief was held the day after the game. Its key points are discussed below.

The primary emotion experienced during the game for the WTL's was one of stress. They felt they had a lot of things to be aware of and to be responsible for. With deeper probing, however, this was found not to be negative, as most WTL reported also finding the experience interesting and valuable. Several WTL's reported that the time seemed to go by quickly, which is suggestive of entering a flow state (Chen, 2007). Further, this somewhat contradictory reporting is consistent with the concept of games' capacity to elicit a state of pleasurable frustration (Gee, 2013).

Even with the reported stress, there was a great level of enthusiasm for the game. Several liaisons suggested expanding the play to take place over two days rather than just one. The suggestion was also to split the players into senior decision-makers and lower-level, on-the-ground decision makers on the second day. The splitting of the strategic teams was hotly debated, and a consensus was not reached in the room.

There was a call for the board to be virtualized. It was felt that this would help with the play, as then everyone could see the game state clearly. In addition, it would allow visualizations of progress or lack of progress to be used in analysis. The virtualization would also help to address the next issue raised.

The participants reported a lack of a sense of consequences for their decisions. If they completed a specific project, they were not sure of the implications on the grander scale. This betrayed the lack of a fail state in the game as it was originally designed and a lack of established ludic goal. In the absence of these, teams were free to create their own interpretations of the goals, but this was at the cost of a sense of the decisions being important to the gameplay. In the future, negative gameplay feedback may be introduced to see how the situation deteriorates if crucial decisions are not made or followed through on.

Some concerns with the realism of the projects were expressed, in particular concerning the banking sector, which some of the projects related to. In reality, the banking sector has more cybersecurity resources at its disposal than many national governments. As such, it may have been unrealistic to create any projects where a national team would step in to provide cybersecurity support.

One of the major recurrent criticisms of seminar wargames—their often linear progression—emerged in the discussion. There were calls to create multiple pathways through the inject deck, leading to a branching narrative. This would increase engagement and allow strategic teams with different strengths to work on problems in parallel. The branching structure would allow the strategic teams to prioritize the questions they felt were important and to have more agency over the game experience. This is an area of potential future research and design.

5. Conclusion

To the author's knowledge, this is the first example of resource management being used in a non-classified seminar wargame. It serves as a proof of concept for the inclusion of these elements to increase both engagement and training value. The various stakeholders have expressed an interest in including this method in further trainings. This has included representatives from industrial partners, who wish to develop the method into a product, as well as members of various military training institutions and centers of excellence. As such, the utility and practicality of the approach has been recognized by both players and game sponsors.

Overall, the design process has been one of initial complexity moving towards simplification. The instinct of the subject matter experts was to attempt to model reality as closely as possible. Yet, the objective of the game was not to accurately reflect the world, but to raise interesting questions for discussion, while remaining understandable to its players.

While game trace data was recorded during the full game session for all 19 teams, the data requires a great deal of processing before it can be examined and publicized, given the sensitive nature of the subject matter. When analyzed, the trace data is expected to provide information on strategic prioritization, demonstrating which projects the ST's felt they had most responsibility for and which they saw as being the responsibility of other sectors. The data could be of use to discussions of policy and strategic studies, as well as to inform future game designs.

The mechanics of this game can be used in other contexts to examine a wide range of topics. Another game using a similar system is currently scheduled for June 2023 and will examine trust in cyber-crises. Futures games can use resources to measure different metrics from money to teams to bandwidth allocation, all of which increase the value of the seminar game.

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Overcoming Social Anxiety: How Virtual Reality and Game-Based Elements are Revolutionizing Patient Therapy

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Abstract: In this paper, we reflect upon the design process and the game-elements for developing a tool for patients. These reflections are based upon a case in where we developed six different Virtual Reality (VR) scenarios as a combined tool for treatment of social anxiety disorder (SAD) for usage within the Danish healthcare system. The core theory for this development is based upon behavioral therapy as a standardized treatment method and the exposure that occur within this. This research is a part of a larger funded project titled VR8, which also contains integration of biofeedback and the application of the practice in where the tool should be applied. The main goal of this paper is to explain the development of the six scenarios, to provide a deeper understanding for the patients on how their anxiety triggers unfolds when exposed to a variety of different scenarios. And to provide a tool for both patients and practitioners to use as an addition to existing treatment methods. The reason for this development is due to (among others) the cost-reduction, time-reduction, heighten of effectivity and user experience in using VR as a tool for treatment compared to regular in-vivo exposure therapy in where the practitioner guides the patient in a physical environment. In this environment a lot of factors can't be controlled and often results in the patient giving up and abandoning the treatment. With VR it is a controlled and closed environment making it more suitable for the patient to interact and level out their anxiety. The combination of iterative design thinking, filmmaking methods, game-based elements and agile software development are used as the core methods to develop the six scenarios. The six scenarios are developed with the aid of specific game-based elements, such as: mapping, level-design, audio control and remote action triggers.

Keywords: Virtual reality, Game-based elements, Social Anxiety Disorder, Cognitive behavioral therapy

1. Introduction

Virtual Reality (VR) has been used as a tool for various purposes, including entertainment, training, and education. However, in recent years, it has been recognized as a potential tool for treating mental health disorders, such as social anxiety disorder (SAD). SAD is a common mental health condition that affects millions of people worldwide. Behavioral therapy, particularly exposure therapy, has been shown to be an effective treatment for SAD. Exposure therapy involves gradually exposing the patient to anxiety-provoking situations until they learn to manage their anxiety. However, traditional in-vivo exposure therapy can be expensive, time-consuming, and challenging for both the patient and the practitioner.

The aim of this paper is to reflect on the design process and the game-elements for developing a tool for patients with SAD. The tool is a combination of six different VR scenarios designed to be used as an adjunct to existing treatment methods. The core theory for this development is based upon behavioral therapy as a standardized treatment method and the exposure that occurs within it. The development of this tool is part of a larger funded project titled VR8 (VR 8 2022), which also integrates biofeedback and its application in the practice where the tool should be applied. To ensure consistency and specificity, an additional goal that might be relevant for this overall research has been identified - investigating how SAD manifests within this type of tool. This is however not a part of this paper since this is a research question on its own and the focus for this paper is mainly on the design and development.

This tool's evolution is a component of a broader funded project titled VR8 (VR 8 2022), which further incorporates biofeedback and its application in the clinical setting where the tool is intended to be used. The multifaceted objectives of this paper are thus aimed at a comprehensive understanding of this tool and its contribution to SAD treatment.

2. Background

Social anxiety disorder (SAD) is a debilitating mental health disorder that affects approximately 7% of the population worldwide (Kessler et al., 2005). Individuals with SAD experience excessive fear and anxiety in social situations, which can significantly impact their daily life, work, and relationships (American Psychiatric Association, 2013). Behavioral therapy is the gold standardized treatment method for SAD, which involves exposing patients to feared social situations. In-vivo exposure therapy involves the patient being guided by the

practitioner in a physical environment. However, in this environment, a lot of factors can't be controlled, which often results in the patient giving up and abandoning the treatment (Kandalaft et al., 2019).

The use of VR technology for the treatment of SAD has gained increasing attention in recent years due to its ability to create a controlled and closed environment (Gerardi et al., 2010; Reger et al., 2011). The use of VR for exposure therapy has been found to be equally as effective as in-vivo exposure therapy, with the added benefit of greater patient satisfaction and engagement (Powers et al., 2008). The use of VR technology in therapy has been shown to be a cost-effective and efficient alternative to traditional in-vivo exposure therapy (Botella et al., 2005). With VR, practitioners can create specific scenarios that trigger the patient's anxiety, making it more suitable for the patient to interact and level out their anxiety (Garcia-Palacios et al., 2007).

VR has many definitions, but one of them is told to be a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real way (Botella et al., 2005). VR technology allows for a controlled and closed environment that can be tailored to the individual's specific needs. This speaks into the usage of VR for various treatment methods due to its controllable nature. In recent years, VR has been used as a tool for treating mental health disorders, such as before mentioned SAD (Gerardi et al., 2010; Reger et al., 2011).

Exposure therapy is a behavioral therapy that has not only been shown to be effective in treating SAD but also dominates as the gold standard for treating SAD (Kampmann et al., 2016; Maples-Keller et al., 2017). Exposure therapy involves gradually exposing the patient to anxiety-provoking situations until they learn to manage their anxiety. These situations are difficult to control in a live environment and provides a lot of challenges for the practitioner. Furthermore, traditional in-vivo exposure therapy can be expensive, time-consuming, and challenging for both the patient and the practitioner due to its many uncontrollable factors (Lindner et al., 2017). Virtual reality (VR), however, provides a more stable environment that can simulate anxiety-provoking situations and allow the patient to practice coping skills in a safe and controlled environment (Parsons et al., 2017). VR also provides a cost-effective and time-efficient alternative to traditional in-vivo exposure therapy (Morina et al., 2015).

The six scenarios in this case were developed to provide a deeper understanding of how the patient's anxiety triggers unfold when exposed to a variety of different scenarios. The scenarios were designed to simulate real-life social situations, such as interacting with unknow people, giving a presentation, and facing public transportation. Each scenario was designed to gradually increase in intensity, starting with low-level anxiety triggers and progressing to high-level anxiety triggers. The patient was guided through each scenario by a therapist, who provided support and guidance throughout the exposure. The criteria for developing these six scenarios were that the scenarios should reflect everyday situations in which the patients were to experience in real life settings. Furthermore, the reason for developing six scenarios was that it was a demand from the overall goal setting within the project of VR8 as mentioned before.

3. Methods

The iterative design process is a methodology that involves repetitive cycles of prototyping, testing, and refining a product or service until a desirable outcome is achieved. This approach is widely used in various fields, including engineering, product design, and software development. According to research by Ramesh et al. (2014), the iterative design process is an effective approach for addressing the uncertainties and complexities involved in product development. The authors suggest that by using iterative design, engineers and designers can improve their understanding of the design problem, test different solutions, and gain feedback from users and stakeholders. Similarly, research by Rouse et al. (2017) highlights the importance of iteration in software development, particularly in agile methodologies. The authors argue that by using iterative design, developers can quickly respond to changing requirements and improve the quality of their software. Overall, the iterative design process has proven to be a valuable approach for creating effective products and in this case with developing a tool that combines both software, filmmaking and testing this method proves to be the most effective for the development and therefore this method was chosen as the core backbone for the process. In this project, we aim to develop a tool that integrates software, filmmaking, and testing. Each of these areas is complex and dynamic, with unique challenges and uncertainties that require a flexible and adaptable approach. The iterative design process, with its cyclic structure of continuous refinement, enables us to systematically address these challenges, test different solutions, and refine our product based on real-world feedback. This cycle of testing and refinement allows us to respond promptly to changing requirements, technological advancements, and evolving user needs, ensuring the development of a

high-quality, user-centered product. Thus, due to its flexible and user-focused nature, the iterative design process has been chosen as the fundamental backbone of our development strategy.

Game elements have been increasingly used as a method for developing 360-degree videos, offering an immersive and interactive experience to users. By incorporating game mechanics, such as points, rewards, and challenges, developers can engage users and motivate them to explore the video content more deeply. According to research by Sánchez-Mena et al. (2018), game elements can enhance the user experience and improve user engagement in 360-degree videos. The article suggests that incorporating game elements can increase users' motivation, sense of achievement, and enjoyment. Similarly, research by Liu et al. (2018) highlights the potential of game elements in 360-degree videos for education and training purposes. The authors argue that game elements can facilitate learning and skill development by providing users with feedback, repetition, and progression. Overall, game elements offer a promising approach for enhancing the development of 360-degree videos and providing a more engaging and interactive user experience. In this case the usage of game elements was incorporated into the guidance and the enhancement of immersion and interaction of the patients using the different scenarios.

The different scenarios were filmed with a 360-degree camera, Insta OneX2 (Insta OneX 2023), and developed in Unity 3D (Unity 3D 2023), which is an opensource game-engine making it possible to add the different game-based elements into the scenarios.

4. The Use of Game-Elements

The use of game-based elements in the development of virtual reality scenarios for the treatment of social anxiety disorder (SAD) has gained increasing attention in recent years. Studies have shown that incorporating game elements such as mapping, level design, audio control, and remote action triggers can enhance the user experience and increase the effectiveness of virtual reality therapy (Hone-Blanchet & Wensing, 2018; Rizzo & Shilling, 2017). Mapping and level design are particularly important in providing a realistic environment for patients to interact with and gradually desensitize themselves to anxiety-provoking situations. Audio control, on the other hand, can help create a more immersive experience, making the scenarios feel more real and heightening the patient's emotional response (Krijn et al., 2004). Remote action triggers, such as the use of handheld controllers, can allow patients to actively participate in the scenarios and provide real-time feedback to practitioners, enhancing the effectiveness of the therapy (Lopes et al., 2020). In this case the remote action triggers were used as the therapist had the opportunity to use the keyboard on the stationary computer while the patient was inside the simulation to make choices the patient couldn’t see.

5. Mapping as Instructions

Mapping is a crucial game element that has been extensively studied in game design and education literature. In games, mapping involves creating a virtual representation of a game world, which players navigate to complete objectives and progress through the game. Studies have shown that mapping can enhance spatial and cognitive skills, as well as increase player immersion and engagement. For example, a study by Kato and Kato (2014) found that game-based mapping exercises improved spatial orientation and navigation skills in high school students. In another study by Ritterfeld et al. (2009), mapping was identified as a key factor in creating a sense of presence and immersion for players. These findings demonstrate the importance of mapping as a game element and its potential to enhance learning and engagement in gaming contexts.

In this case mapping was used as instructions for the therapist to make sure that they knew which choice to make for the patient and what path to take within the simulation. the way it was made was with an “overlay” only visible for the therapist and not for the patient. This overlay provided the therapist with all the information that he needed to know where in the simulation the patient was. Below is a figure (figure 1) illustrating the overlay seen on the therapist’s screen directing them of what to do next. The green text is not visible to the patient within the headset.

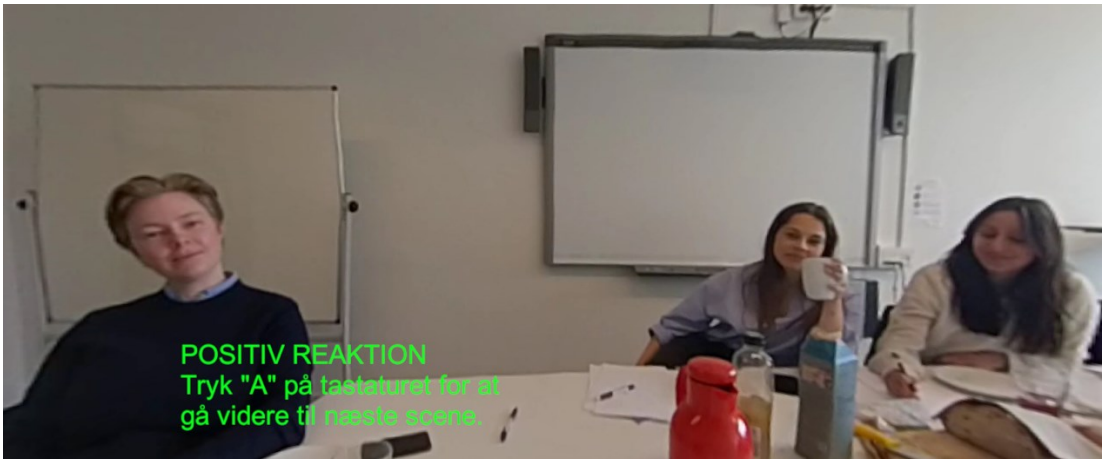

Figure 1: Picture from the "Job Interview" showing the green overlay which tells the therapist to press "A" on the keyboard to provide a positive reaction to the patient's presentation

6. The Design Process

The design process for developing the VR tool for SAD treatment involved several methodologies and approaches, which have been extensively studied and applied in the fields of design, filmmaking, game design, and software engineering. The iterative design thinking process has been widely used in product and service design and involves continuously refining and improving a design based on feedback and user testing (Kumar, 2019). Filmmaking methods, such as storyboard development and shot planning, have been applied in the development of VR experiences, as they help to create a narrative structure and visual coherence (Jerald, 2015). Game-based elements, including mapping, level-design, audio control, and remote action triggers, have been used in game design to create immersive and interactive experiences (Fullerton, Swain, & Hoffman, 2008). Finally, agile software development has been widely used in software engineering, as it enables the development team to quickly respond to changing requirements and deliver software in iterative cycles (Beck, Beedle, Van Bennekum, Cockburn, & Cunningham, 2001).

The design process for the VR tool began with user research, including interviews and surveys with patients and practitioners, which is a common practice in user-centered design (Norman & Draper, 1986). This research helped to identify the target audience and specific needs of patients with SAD, as well as anxiety-provoking scenarios based on their real fears. The data gathered from these research methods was used to develop six different VR scenarios, which were tested and refined based on user feedback. The use of agile software development ensured that the software met the design requirements, and that the development process was closely tied to the design process, enabling quick changes and improvements to be made.

7. The six VR Scenarios

The six different VR scenarios were designed to simulate anxiety-provoking situations commonly experienced by patients with SAD. The scenarios were designed to be used in conjunction with traditional in-vivo exposure therapy as an adjunct treatment method. The scenarios were as follows: 1: A bench scenario: In this scenario the patient is placed on a bench in a park with an unknown person who then interacts in various ways with the patient, inducing confrontational fears and gradually makes it possible for the patient to be challenged within the simulation. This scenario consists of 14 different scenes. 2: A Job interview: This scenario simulates a job interview and is designed to help patients overcome their fear of interacting with people whom they don't know and to share personal details with other people. This scenario consists of 21 different scenes. 3. A presentation scenario: In where the patient is induced to the fear of public speaking and are to hold a presentation in front of an audience. To cope with the fear, it is possible for the patient to choose doing the presentation in a sitting or standing manner. This scenario consists of 15 different scenes. 4. A shopping scenario: This scenario simulates a shopping experience, which is gradually increasing situations with asking store personnel, getting confronted with awkward situations while waiting in line, asking for help, and smashing an egg in front of other costumers. This scenario consists of 20 different scenes. 5. A Café Scenario: In where the patient is confronted with ordering and receiving food they didn't order. The choices are varied in different ways challenging the patient to say no. This scenario consists of 34 different scenes. 6. Public transportation: This scenario simulates a train public transportation situation and is designed to help patients

overcome their fear of awkward situations and being on a public transportation in where they cannot flee. This scenario consists of 30 different scenes.

8. Overview of Game-Based Elements and User Guidance in the Product Distributed on the Scenarios

Below is a table (table 1) showing the different game elements within the scenarios. And how they are used as guidance for both the patient and the therapist. In the table there are short descriptions of the various game-based elements used within each of the scenarios.

Table 1: Game-Based Elements occurring within each scenario, including the user guidance for both the patient and the therapist

Scenario	Game-based element	User guidance (Patient)	User guidance (Therapist)
1. A bench Scenario	Mapping, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices.
2. A Job interview	Mapping, sound effects, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices. Sound effects.
3. A presentation scenario	Mapping, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices.
4. A shopping scenario	Mapping, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices.
5. A Café Scenario	Mapping, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices.
6. Public transportation	Mapping, arrows for direction, textboxes, remote action triggers.	Arrows for direction, textboxes for prompting choices.	Mapping with text as instructions, remote action triggers to make choices.

In the table (Table 1), various game-based elements are outlined as follows: mapping, directional arrows, text boxes, sound effects, and remote action triggers. These components were perceived in the following ways in this case. Mapping, with an overlay, was accessible to the therapist, enabling them to guide the path or choices within the simulation. This system acted as a navigational aid, allowing the therapist to have a continuous understanding of the patient's position within the simulation. Furthermore, it permitted the manipulation of anxiety-inducing scenes by offering choices within the scenario, increasing, or decreasing the intensity as necessary. Directional arrows, akin to those utilized by Google Maps (Google Maps, 2023), were employed to facilitate the patient's comprehension of movement within the scenes, and to enable teleportation to the next location. An "eye-gaze mechanic" within the VR simulation assisted this process, causing scenes to fade and transition smoothly as the patient moved and focused on the arrows. Sound effects were deployed to enhance anxiety levels in the job interview scenario, specifically using the sound of a drill to increase the challenge for the patient when interacting with other characters. This auditory stimulus was managed by the therapist and could be toggled on or off via a keyboard command. Text boxes were used to make the patient's choices explicit, effectively breaking the immersive quality of the simulation. Hence, when the patient was given a choice, a text box with either Choice A or Choice B appeared before them, with the eye-gaze mechanic enabling selection. Lastly, remote action triggers allowed the therapist to make decisions on behalf of the patient without their knowledge, using keyboard commands. This feature afforded the therapist the ability to modulate the anxiety levels within each simulation, thereby facilitating gradual exposure of the patients to fear-inducing situations.

The game elements indeed play crucial roles here. However, to better illustrate their application in terms of Social Anxiety Disorder (SAD), it's important to emphasize how each game mechanic interacts with the triggers and symptoms of this condition. For example, the sound effects can simulate a stressful social environment, potentially mirroring the patients' experiences during real-life social interactions. Similarly, the directional

arrows and text boxes can serve as metaphors for the struggle of choice-making in social scenarios often experienced by individuals with SAD. Therefore, these game elements not only construct a replicative virtual scenario but also facilitate the therapeutic process by systematically challenging and alleviating the patients' fears and anxieties in a controlled, safe environment.

9. Summary and Conclusion

The use of game-based elements such as mapping, level design, audio control, and remote action triggers in virtual reality scenarios for the treatment of social anxiety disorder (SAD) has been drawing attention in recent years. Studies suggest that incorporating these elements can heighten the user experience and augment the efficacy of virtual reality therapy. Mapping and level design offer a realistic environment in which patients can interact and gradually desensitize themselves to anxiety-provoking situations, while audio control contributes to a more immersive experience. Remote action triggers, like handheld controllers, empower patients to actively engage in the scenarios and provide real-time feedback to practitioners, thereby amplifying the therapy's effectiveness.

These concepts are currently being explored further in the context of a larger Randomized Control Trial (RCT) study within the VR8 project. This ongoing study has been instrumental in the design process for developing the VR tool for SAD treatment, involving a variety of methodologies and approaches, including user research, iterative design thinking, filmmaking methods, game-based elements, and agile software development.

In the context of this study, six different VR scenarios simulating anxiety-provoking situations commonly experienced by patients with SAD were designed and subsequently refined based on user feedback. It's worth noting that these scenarios are a part of this larger RCT study and are yet to be fully tested, with the results not due yet. The design intention is for these scenarios to be used in conjunction with traditional in-vivo exposure therapy as an adjunct treatment method.

In conclusion, the use of game-based elements in the development of virtual reality scenarios appears to have immense potential in enhancing or perhaps even revolutionizing the effectiveness of therapy for social anxiety disorder. As the findings from the ongoing RCT study are not yet available, the true potential of these innovative tools remains to be seen.

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The Design, Implementation and Evaluation of Gamified Immersive Virtual Reality (IVR) for Learning: A Review of Empirical Studies

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Abstract: The reduced cost of Virtual Reality (VR) technology makes it possible to be used in education. And the virtual learning scenarios in immersive virtual reality (IVR) contain some kind of gamification in the design aspects. Though some published reviews mapped the application of IVR in education, reviews about the use of gamification in IVR in education are still under research. In this review, game elements, game mechanisms, learning performance evaluation, research design, and methods were extracted from the selected empirical articles from Web of Science, Scopus, and Google Scholar after rigorous inclusion and exclusion. It found that learning interactions inside the IVR learning scenarios frequently consisted of interaction with virtual objects or equipment, interaction with avatars (non-Player Characters (NPC)), interaction with avatars (participant displayed as an avatar), and watching the video in a follow-the-machine view. The most popular three gamification mechanisms were rewards, challenges, and avatars, while the most common gamification elements utilized were content unlocking, a point system, task difficulty levels, NPC, an achievement system, role-playing, and a progress bar. Action error rates and test scores were the popular learning performance measurement metrics. In general, positive learning performance was more related to the number of game mechanisms rather than the number of game elements. Gamified IVR programs facilitated learning engagement, learning motivation, collaborative ability, declarative knowledge learning, and procedural knowledge and skills learning especially for novice trainees. Some high abstract focus areas like algebra in mathematics might not be suitable for IVR-based instruction even combined with the use of gamification. Some recommendations and future research directions were given such as how to help integrate gamified IVR learning materials with normal education or training and how to improve simulator sickness, more attention to diverse learning performance measurement, collaborative learning in IVR, learning theories or pedagogical strategies adopted in gamified IVR-based instruction.

Keywords: Gamification, Game factors, Learning outcomes, The interaction mechanism, Empirical studies

1. Instruction

In the digital age, gamification or games is a buzzword that appears in a bunch of academic disciplines and industries. In education, serious educational games and serious games are common terms used for the main purpose of knowledge acquisition and skills development through the design of digital games (Annetta, 2010). Game-based learning displays a learning environment where a sense of achievement could be satisfied through problem-solving activities using game content and gameplay to enhance knowledge and skills acquisition (Qian & Clark, 2016). Compared to serious games and game-based learning which are mostly represented by some educational game products, gamification is a process of the application of game elements in a non-game context (Deterding et al., 2010). This review adopted the term gamification because it is a broader concept utilizing game components and applying them in the real environment (Krath, Schürmann & Von Korflesch, 2021).

Much research demonstrated the benefits of gamification in education. For example, a review by Nurtanto et al. (2021) indicated that gamification produced positive impacts on cognitive, affective, and behavioural learning outcomes. Meta-analysis of the effects of gamification on behavioural change in the educational context indicated moderate and positive grand effects sizes of gamification on learning outcomes (Kim & Castelli, 2021). However, it also attracted controversies and critiques, like loss of performance and gradual loss of motivation (Toda, Valle & Isotani, 2018). A mixed-method review by Bai, Hew, and Huang (2020) extracted two reasons why gamification was disliked by some learners including bringing no additional utility and causing anxiety or jealousy. One variable is the technological delivery of the gamified intervention.

In contrast with desktop VR simulation and conventional lectures, similar learning content delivered through IVR induced intrinsic motivation and self‐efficacy (Makransky, Borre‐Gude & Mayer, 2019). The meta-analysis by Wu, Yu and Gu (2020) observed that IVR using head-mounted displays (HMDs) was more effective than non-immersive learning approaches. On the other hand, Elford, Lancaster, & Jones (2021) put forward that to avoid the superficial combination of learning content and gamification, the integration of meaningful game mechanics relevant to pedagogical objectives was highlighted. Few reviews of the use of gamification

have been done in the research field of IVR in education. Therefore, to fill this research gap several research questions were proposed in this review.

2. Theoretical Background and Research Questions

Generally, gamification includes two aspects, namely game elements and game mechanisms. The major game elements are achievements, avatars, badges, content unlocking, gifting, leaderboards, levels, points, quests, teams, and virtual goods (Buckley and Doyle, 2017). Regarding game mechanisms, Werbach and Hunter (2015) put forward a game elements pyramid to describe how motivation could be triggered by gamification. This framework consisted of three different levels and the logic behind it was that components generate mechanics which produce dynamics. Luo (2022) emphasized that the definition of game elements and mechanisms may explain the various effects of gamification for educational purposes and suggested a redefinition of these two terms. It means, identifying game elements and mechanism is crucial for the evaluation of learning performance in gamified learning environments.

Few reviews were found to analyze the impact of gamified IVR programs on learning performance in education. Loureiro, Bilro and de Aires Angelino (2020) conducted a VR and gamification review in higher education to present the most important topics. But this review separately searched the terms VR and gamification, which means it was more likely a combination of two reviews in the marketing or service of higher education. Pinto et al. (2021) investigated whether gaming strategies in virtual reality benefit the learning of a second or foreign language. They identified augmented reality as the learning used technology, and more than half of the selected articles proved the usability of VR technologies with gaming strategies. It can be concluded that VR esp. IVR technology did not take a major role in this review. There are review articles on gamification and education, however, there are few on the use of gamification use of IVR in learning. The picture is even unclear when it comes to the design, implementation, and evaluation of gamified IVR in education. In addition, based on the systematic review of IVR application by Radianti et al. (2020), the theoretical application was seldom thought about during the development of educational VR programs for improving learning effects. Won et al. (2023) pointed out that more attention should be paid to the way the learning tasks were designed when conducting a review study to the analysis of empirical studies on IVR. Therefore, several research questions were proposed:

Question 1: What research design and methods were used in gamification research about learning using IVR?

Question 2: What kinds of game elements, game mechanisms, and interaction mechanisms were common in the learning of using IVR?

Question 3: What are the underlying theoretical models or theories or principles used in gamification research about learning using IVR?

Question 4: What kind of learning performance appeared in the studies about learning using IVR? How were these learning performances measured?

Question 5: The relationships between game elements and mechanisms and learning performance?

3. Research Design

3.1 Research Method

Given the design of VR-based teaching would significantly influence the costs and energy invested and the learning effects produced, a systematic mapping approach to the previous articles by extracting key design elements, mediating variables, and expected learning performances is important. This review followed the updated preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Page et al., 2021).

3.2 Review Process and Literature Search Method

Web of Science, Scopus, and google scholar was selected as the search databases because they cover the fields of social science, information technologies, medicine, and humanities and own a huge amount of data. Other databases were aware, such as Science Direct and Taylor & Francis, but we expected most of the articles they own already be part of the databases we chose.

Regarding our database search, three parts of the search string were identified, gamification, immersive virtual reality, and education. The details could be found at the link: https://github.com/wentingsunhu/Gaminification-IVR.git

3.3 Inclusion and Exclusion Criteria

To extract related information, rigorous inclusive and exclusive criteria were set. The details could be found at the link: https://github.com/wentingsunhu/Gaminification-IVR.git

In total, three databases produced 2253 search results, and 14 were left after scanning the title and abstract, eligibility assessment, and extracting answers for related research questions. The searching and selecting process following PRISMA could be found by the link: https://github.com/wentingsunhu/Gaminification-IVR.git

3.4 Data Extracting and Coding

The following key information was extracted from each article: general information, IVR technologies, research design and methods, underlying theories, learning tasks, learning interaction, adopted gamification elements and mechanisms, learning performance, and measurement metrics. The related key information was directly extracted from the selected articles and supplementary materials. The coding schemes of game elements and game mechanics initially referred to the articles of Buckley and Doyle (2017) and Werbach and Hunter (2015) and were added other items when other game elements were narrated in the selected articles.

4. Results and Analysis

Some of the coding results of research design, research method, underlying theories, and learning performance evaluation were summarized below. More details of coding results could be found at the link: https://github.com/wentingsunhu/Gaminification-IVR.git

4.1 General Information

Nearly 72% of the participants come from university (10 out of 14) and 14% of participants are adult learners (2 out of 14). One article chose a secondary school, and one chose an elementary school. The most popular focus areas were engineering (4 out of 14) while the second most popular was biology and medicine (both were 2 out of 14). Out of 14 articles, 5 articles are part of a normal curriculum or training program and 5 are not. It was studied that most of the selected studies employed HTC VIVE as their high-end HMDs. Out of 14 papers, 8 were developed by the author team while 3 by collaboration with software development companies, and 3 articles utilized the commercially available VR software.

4.2 Research Design and Methods (Question 1)

Some important features of research design and methods were summarized in Table 1. 64% of research utilized quantitative methods and 29% of them used mixed research methods. Among them, descriptive analysis, ANOVA, t-test, and ANCOVA were frequently used in the quantitative method. Different kinds of comparison groups could be found in table 1.

Regarding the pre-activities before the intervention, 57% of the experiment provided VR manipulation training, and 29% of them organized debriefing or discussion about the learning content (Oberdörfer & Latoschik (2019), Elford, Lancaster, & Jones (2021), Wee & Lim (2022), Süncksen et al. (2018)). Besides, the research procedure introduction (Wee & Lim (2022), Šašinka et al. (2018), Ulmer et al. (2022)) and corresponding lectures before experiments (Yang & Oh (2022), Oberdörfer & Latoschik (2019)) were also seen.

Table 1: Research Design and Methods in Gamified IVR in Education

Research methods	Quantitative methods	ANCOVA (Yang & Oh (2022); Wee & Lim (2022); Ou, Liu & Tarng (2021))
		ANOVA (Yang & Oh (2022); Oberdörfer & Latoschik (2019); Wee & Lim (2022); Ou, Liu & Tarng (2021))
		t-tests (Wee & Lim (2022); Larsen et al. (2023); Kwon (2019); Ou, Liu & Tarng (2021))
		Chi^2 test (Palmas et al. (2019))

		Descriptive analysis (Süncksen et al. (2018); Tan et al. (2022))
	Qualitative methods	An experiential qualitative approach of Interpretative Phenomenological Analysis (IPA) (Šašinka et al., 2018)
	Mixed (besides interview in qualitative method)	Descriptive analysis (Elford, Lancaster, & Jones (2021); Chen (2020))
		Shapiro–Wilk test (Tsirulnikov et al. (2023))
		Pearson correlation, one-sided Mann-Whitney U tests (Tsirulnikov et al. (2023))
Comparison groups	Enhanced IVR group	Kwon (2019)
	Simulation group	Yang & Oh (2022); Elford, Lancaster, & Jones (2021)
	AR group	Elford, Lancaster, & Jones (2021)
	Non-gamified IVR version group	Oberdörfer & Latoschik (2019); Chen (2020); Larsen et al. (2023); Ulmer et al. (2022); Palmas et al. (2019)
	A video lecture with a keyboard and mouse	Wee & Lim (2022)
	Desktop VR group	Ou, Liu & Tarng (2021)
	Paper-based group	Ulmer et al. (2022)

4.3 IVR Learning Scenarios Design (Question 2)

The top 3 learning interactions inside the IVR learning scenarios consisted of interaction with virtual objects or equipment, interaction with non-player characters avatars (NPC), interaction with Player avatars, and watching the video in a follow-the-machine view. One thing that needs to be noticed is that this review didn't consider the basic interaction within the VR scenarios, like immediate feedback and moving around because almost all IVR programs own these interaction features.

Various gamification elements were identified from the selected articles. As shown in Table 2, the most popular three gamification mechanisms were rewards, challenges, and avatars, accounting for 31%, 29%, and 12% respectively while the common gamification elements utilized were content unlocking, a point system, task difficulty levels, NPC, an achievement system, role-playing and progress bar. 79% of the IVR tasks were finished by individuals and the rest were finished by a team (Oberdörfer & Latoschik (2019), Elford, Lancaster, & Jones (2021), Šašinka et al. (2018)).

Table 2: Game Elements and Mechanisms, Interaction Mechanisms in Gamified IVR Educational Programs

Game elements and mechanisms	Challenges	Quests (Yang & Oh (2022)), content unlocking (Yang & Oh (2022); Elford, Lancaster, & Jones (2021); Wee & Lim (2022);Kwon (2019);Tsirulnikov et al. (2023)), task difficulty level system (Oberdörfer & Latoschik (2019);Chen (2020);Ulmer et al. (2022);Süncksen et al. (2018)), an escape scenario (Oberdörfer & Latoschik (2019);Ou, Liu & Tarng (2021))
	Rewards	Thumb-up (Yang & Oh (2022)), congratulation prompt (Ou, Liu & Tarng (2021)), an achievement system (Oberdörfer & Latoschik (2019); Wee & Lim (2022); Kwon (2019)), a badge (Chen (2020)), trophies (Wee & Lim (2022)), a point system (Oberdörfer & Latoschik (2019); Chen (2020);Tsirulnikov et al.

		(2023);Ulmer et al. (2022);Süncksen et al. (2018)); particle effect as rewards (Palmas et al. (2019))
	Avatar interaction	NPC (Yang & Oh (2022); Wee & Lim (2022); Larsen et al. (2023)- avatar instructor and avatar as patient;Kwon (2019)); participant avatar (Elford, Lancaster, & Jones (2021) ;Šašinka et al. (2018))
	Feedback in asking for content	A debriefing system (Oberdörfer & Latoschik (2019)), a small built-in wiki (Oberdörfer & Latoschik (2019))
	Status	Progress bar (Chen (2020); Tsirulnikov et al. (2023); Palmas et al. (2019))
	Competition	Leaderboard (Chen (2020))
	Storyline	Narrative context (Wee & Lim (2022))
	Role-playing	Role-play as a professional human (Kwon (2019); Tan et al. (2022)), role-play as an animal (Ou, Liu & Tarng (2021))
	View switch	Map switch between 2D and 3D (Šašinka et al. (2018))
VR scenarios interaction	Interaction with avatars (NPC)	Yang & Oh (2022);Larsen et al. (2023);Kwon (2019)
	Interaction with avatars (participant displayed as an avatar)	Elford, Lancaster, & Jones (2021); Šašinka et al. (2018)
	Interaction with virtual objects or equipment	Yang & Oh (2022); Oberdörfer & Latoschik (2019); Elford, Lancaster, & Jones (2021); Chen (2020); Wee & Lim (2022); Larsen et al. (2023); Kwon (2019); Tsirulnikov et al. (2023); Šašinka et al. (2018); Ou, Liu & Tarng (2021); Ulmer et al. (2022); Süncksen et al. (2018); Palmas et al. (2019)
	Watch the video in a Follow-the-machine view	Tan et al. (2022)

4.4 Underlying Theoretical Models or Theories or Principles (Question 3)

The Underlying Theoretical Models or Theories or Principles mentioned in the selected papers have two parts, one in VR program design and another in the analysis of the experiments. As illustrated in Table 3, game-based learning and simulated learning appeared more frequently. Most of the theories only appeared once, like Gamified Knowledge Encoding model (Yang & Oh (2022)). Only five articles employed theories in their analysis parts such as Keller's ARCS model (1987) (Yang & Oh (2022)), and situated experiential learning (Elford, Lancaster, & Jones (2021)). Only two of them pointed out that they follow the structure of traditional class-based learning (Oberdörfer & Latoschik (2019); Larsen et al. (2023)) and two of them emphasized that they follow the guidelines set by industry or professional associations (Yang & Oh (2022), Süncksen et al. (2018)).

Table 3: Underlying Theoretical Models or Theories or Principles Used in Gamified IVR Educational Programs

Underlying theories	In design part	Gamified Knowledge Encoding model (Yang & Oh (2022)); simulated learning (Yang & Oh (2022);Ou, Liu & Tarng (2021)); escapED framework (Oberdörfer & Latoschik (2019)); motivation theory (Chen (2020)), empirical learning (Kolb,1984) (Kwon (2019)),

		collaborative learning (Šašinka et al. (2018)), game-based learning (Chen (2020); Kwon (2019);Ou, Liu & Tarng (2021); Süncksen et al. (2018); Palmas et al. (2019)), Self Determination Theory (Ulmer et al. (2022)), active learning (Tan et al. (2022))
	In analysis part	Keller's ARCS model (1987) (Yang & Oh (2022)); situated experiential learning (Elford, Lancaster, & Jones (2021)); embodied cognition theory (Wee & Lim (2022)), expectancy-value theory of motivation (Tsirulnikov et al. (2023)), Kirkpatrick's four-level model (Tan et al. (2022))

4.5 Learning Performance and Evaluation (Question 4)

From the perspective of types of knowledge learning, 57% of the learning tasks belonged to declarative knowledge learning and the rest were procedural or practical knowledge and skills learning. In terms of the former, more frequent performance metrics were error rates and completion of tasks or completion time. And for the latter, test scores especially rating surveys and multiple-choice questions were used more. More information could be found in Table 4.

For the learning experience, more variables were identified. In positive aspects, representational fidelity, learning motivation, learning efficacy, perceived usefulness, perceived ease of use, and intention to further use were common while learning anxiety, mental workload, and simulator sickness appeared more often in negative aspects.

Table 4: Learning Performance and Evaluation

Learning tasks	Practical or procedural knowledge and skills practice	Error rates (Chen (2020); Ulmer et al. (2022); Palmas et al. (2019))
		Completion of tasks or completion time (Chen (2020); Ulmer et al. (2022); Palmas et al. (2019))
		Test score- knowledge correction judgment (Yang & Oh (2022))
		Test score- rating survey (Süncksen et al. (2018))
		Test scores- the sum of points (Larsen et al. (2023))
	Declarative knowledge learning	Test score-correct rates in paper exams (Oberdörfer & Latoschik (2019))
		Completion time (Elford; Lancaster, & Jones (2021))
		Test scores-short answers (Wee & Lim (2022))
		Test scores-rating survey (Kwon (2019); Tan et al. (2022))
		Test scores-multiple-choice questions (Tsirulnikov et al. (2023); Ou, Liu & Tarng (2021))

4.6 Relationship between Focus Areas, Gamification Elements and Learning Performance (Question 5)

To better organize the relationships between game elements and learning performance, focus areas were used to explore the mixed results. In general, gamified IVR program produced positive learning performance in Engineering. For the programming concepts of comprehension and misconceptions addressed in the study of Wee & Lim (2022), both video lectures and gamified IVR groups showed a significant increase in declarative Knowledge learning while the IVR intervention was rated to be more engaging significantly. But both groups expressed a comparatively high level of frustration and mental load. In assembly, Ulmer et al. (2022) demonstrated that in the completion of tasks, Gamified-VR-Group had a significantly lower total assembly

time and fewer errors compared to Non-Gamified-VR-Group. Palmas et al. (2019) observed that the use of gamification in the conducted VR training simulation particularly benefitted VR novice participants in aspects of transfer-oriented knowledge learning and practical skills. The IVR scenario about the operation of Powder-bed binder jetting 3D printing technology in Chen (2020) was the only IVR program users felt confused about the IVR interaction even after going through the operation tutorial, but the simulation degree of the prototype's interactions and visual presentation was given positive responses.

Positive evidence in learning outcomes and experience was also found in the gamified biology IVR program. In the study by Tsirulnikov et al. (2023), learning motivation, learner engagement, and perceived ease of use were documented as very positive and participants had increased test scores following the laboratory simulations. The learning effectiveness and engagement of the HMD VR group were significantly higher than desktop VR (Ou, Liu & Tarng (2021).

In medicine, the results of Larsen et al. (2023) indicated that the IVR modules had the potential to be adopted as unsupervised out-of-hospital training for novice trainees while gamified IVR sessions were widely appreciated as providing a user-friendly and sufficiently realistic training tool with a high educational value for intraoperative C-arm imaging in Süncksen et al. (2018).

In both gamified geography and chemistry IVR programs, participants demonstrated positive feedback in the development of communication abilities facilitated by the presence of player avatars (Elford, Lancaster, & Jones (2021); Šašinka et al. (2018)).

In an elementary science course to explore the Earth and Moon (Kwon, 2019), to provide locomotive and tactile interactivity indirectly in the Authentic virtual reality (AVR) group, PlayStation 4 (PS4) gamepad was connected to the HTC VIVE, which means more could be researched in terms of representational fidelity. Though the same type of HMD was adopted, the AVR group reported a stronger feeling of being in a virtual space. At the same time, tactile interactivity and experientiality were significantly enhanced. Besides, simulator sickness in the AVR showed significant relief. Learning performance in the AVR group was significantly enhanced regarding analysing, evaluating, and creating questions. The gamification mechanisms in the gamified mathematics IVR program were challenges, rewards, interaction with NPC instructors, and role-playing.

Though six game elements were identified in the gamified mathematics IVR program, the learning performance in mathematics seemed not effective (Oberdörfer & Latoschik, 2019). No improvement was tested in transfer-oriented knowledge learning after the intervention of the IVR session and no difference in effectiveness and efficiency were drawn.

An outperformance was observed in nursing (Yang & Oh, 2022). Compared to the simulation group declarative Knowledge learning, Problem-solving ability, learning efficacy, and learning motivation were improved. The game elements used in this focus area facilitate the interaction between users and NPC patients, virtual equipment, combining challenges and instant rewards.

5. Discussions and Implications

As to the design part, compared to the number of game elements employed, diverse game mechanisms in the design of the gamified VR program were more significant. As analysed in part 4.7, the number of game elements didn't directly relate to learning performance. One potential explanation may lie in the deep combination of game mechanisms with learning content.

Though the application area is education, few learning theories or pedagogical strategies were employed either in the design or analysis of the application of gamified IVR. Like Radianti et al. (2020), this review also calls for more efforts in proposing a taxonomy of learning theories and other framing factors for educational VR applications.

Learning performance measurement instruments are necessary to be paid attention. Most of the measurements of the learning performance were to test whether users can correctly follow or answer the given procedural tasks or multiple-choice questions without guidance. Error rates and completion of tasks or completion time frequently were emphasized.

For high mental workload learning materials, how to design learning activities in gamified IVR sessions is still under-researched. For instance, in the study by Wee & Lim (2022), both the gamified IVR group and video

lecture group experienced somewhat high levels of mental load. Also, it is also important to discuss similar questions in some highly abstract learning materials like Algebra (Oberdörfer & Latoschik, 2019).

It seems that collaborative learning in gamified IVR sessions produces a good learning experience. The virtual collaborative context in the gamified IVR sessions provides shared learning regulation chances for players as part of their imagination comes to life and becomes collaborative visualization. It could be deduced that more players' working memory could be used to deal with tasks, which may be explained by situated learning theories but realized in a virtual way.

Simulator sickness is a popular topic in VR applications. But this review didn't recognize serious sicknesses after the intervention of gamified IVR in spite of the duration of the gamified IVR scope from less than 10 mins to no time limit. One common thing in all selected papers is the usage of high-end HMDs. So possibly it could be inferred that the resolution of IVR programs impact simulator sickness.

6. Limitations and Conclusions

For limitation, only gamified IVR application in education was looked at. Many VR serious games or VR educational games were not selected. They might own a high level of maturity and have been successfully utilized in education. Then, the small scope of the databases and research methods chosen impacts the generation of the results of the review. All these factors restrict the validity of our conclusions.

In summary, this review analyzed the common game elements and game mechanisms and their relationships with learning performance in gamified educational IVR applications. It was observed that the most popular game mechanisms were rewards, challenges, and avatars, and positive learning performance was more related to the number of game mechanisms. Meanwhile, diverse learning performance measurements, collaborative learning in IVR, learning theories or pedagogical strategies adopted in gamified IVR-based instruction were suggested for further research.

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Masters Research Papers

A Proposed Framework for the Classification of Game-Based Learning in Construction Management

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Abstract: As the construction industry heads towards the Fourth Industrial Revolution, the gap widens between industry demands and fresh graduate capabilities. Much of this is owed to the traditional Construction Management (CM) pedagogy. Therefore, there is a pressing need for a paradigm shift in our approach towards CM education. As such, to meet both industry demands and student expectations, integrating game-based learning (GBL) can substantially enhance the learning experience for CM students in higher education. Although the body of knowledge recognises Game-Based Learning (GBL) as tools that facilitate active learning in engineering disciplines in general, their utilisation remains limited in construction management. Thus, the aim of this paper is to conduct a systematic literature review of past GBL studies in Construction Management via Scopus database with an attempt to classify these studies into three broad categories: Tabletop games, digital games, and computer-assisted games. First, this paper will explain the key features, strengths, and limitations of each category. Second, this paper will identify the trends in game characteristics, learning objectives, data collection methods, and game evaluation approaches. Finally, this paper will present a classification framework that summarises the findings to facilitate selecting effective GBL strategies for CM higher education. Thus, this study will provide a wide-lens view of the research trends, gaps, and future research recommendations in this field as well as present design parameters for effective GBL integration.

Keywords: Game-Based learning, Simulation games, Construction management, Higher education, Experiential learning

1. Background

As the construction industry heads towards the Fourth Industrial Revolution, the gap widens between industry demands and fresh graduate capabilities (Castronovo et al., 2022). In today's fast-paced digital age, there are three key industry needs for construction managers: strong theoretical understanding, adept technical skills, and transferable soft skills (Ojiako et al., 2011, Castronovo et al., 2022). This demand is compounded by the increasing difficulty of continuing professional development after employment due to the intensive work demands of the industry (Wall & Ahmed, 2008). As such, the challenges and limitations of traditional CM pedagogy have gained considerable attention and scrutiny in recent years to ascertain the necessary changes for bridging the gap between academic training and industry demands (Ojiako et al., 2011, Pereira & Thom, 2022).

Past studies investigated this phenomenon in an effort to understand the causes behind this gap. For example, Lee, Samad, and Goh (2020) attributed this struggle to passive teaching methods where a plethora of information is presented abstractly. Similarly, Herrera et al. (2019) stated that the lack of immersion in the subject was a major detriment of traditional lecturing, especially for students without prior exposure to the industry. In addition, Dancz et al. (2017) and Pereira & Thom (2022) recognised the pressure on the curriculum itself to continually improve its evaluation methods, provide practical training opportunities, and train communication skills for students of diverse learning backgrounds. Moreover, a survey conducted by Ojiako et al. (2011) revealed that the expectations of the 'digital native' student, who grew up with digital technology, have changed significantly in line with contemporary industry demands. Most notably, respondents of the survey placed high importance on the development of transferable skills and the effective use of virtual learning tools (Ojiako et al., 2011). Therefore, there is a pressing need for a paradigm shift in the way we approach teaching CM, and integrating simulation games can substantially enhance students' learning experience in higher education.

Game-Based Learning (GBL) is a teaching practice under Experiential Learning Theory (ELT). It describes learning as a unique process for every learner rather than a shared outcome (Kolb & Kolb, 2017). From their modern guide for experiential educators, Kolb and Kolb's (2017) model for the ELT learning cycle comprises of four stages: concrete experience/abstract conceptualisation for grasping experience and active experimentation/reflective observation for transforming experience. Although hands-on learning is used interchangeably with experiential learning, the authors clarified that experience represents only one stage of the learning cycle. In traditional CM pedagogy, class lectures, assignments, group projects, and internships offer half of the learning cycle (concept and experience) but often lack qualitative feedback (reflection) or

experimentation (action) without adversely affecting their class performance grade. On the other hand, integrating game-based learning allows students to transform new knowledge in a risk-free environment with personalised feedback (Oo & Lim, 2016, Perini et al., 2018). Thus, CM education can greatly benefit from this holistic approach, which complements the nuanced and multidisciplinary nature of the CM field.

Within ELT, there are several practices documented in the literature, of which simulation and gaming is one of them (Kolb & Kolb, 2017). Simulation and gaming refer to a pedagogical approach that uses a serious game or simulation model that emulates a system or process to better recognise its underlying principles and mechanisms (Kriz, 2017). This paper focuses on one genre of games called simulation games. A simulation game models a real-life system or process and adds game objectives to visualise the underlying principles in an interactive and engaging environment (Kriz, 2017). Furthermore, simulation games vary in complexity and realism, and they have supported educators, policymakers, and researchers for several decades (Kriz, 2017). For students in CM higher education, this paper argues that simulation games are the most suitable form of experiential learning due to their visual, interactive, adaptive nature.

Simulation games greatly complement the CM discipline. Primarily, they allow learners to interact with complex systems in a controlled and simplified manner (Fumarola, van Staalduinen, & Verbraeck, 2012). In the workplace, experimentation comes with high cost, uncertainty, and risk (Miettinen et al., 2016); likewise, grade penalties create a barrier to experimentation in academic settings (Dib & Adamo-Villani, 2014). On the other hand, working in a virtual environment encourages students to unlock their creativity and explore new paths that may never see real implementation otherwise (Perini et al., 2018). For example, learners can test different decision paths and witness their subsequent outcomes (Dib & Adamo-Villani, 2014). Moreover, simulation games provide immediate and personalised feedback (Hassan, Haghighi-Rad, & Abtahi, 2021). According to Castronovo et al. (2022), engaging students to test their hypotheses and strategies in fast cycles motivates and helps them gain problem-solving skills and awareness of their own learning.

Lastly, simulation games give students first-hand experience interacting with the subject material in-context which reinforces their theoretical knowledge (Oo & Lim, 2016). Therefore, simulation games are valuable tools for teaching the underlying principles of a complex system in a visual, interactive, and practical way with low risk. The type of game also has an influence on the experiential skills being trained. Multiplayer games can foster collaboration and healthy competition among students, as they rely on active communication and group problem-solving (Perini et al., 2018). On the other hand, single-player games require students to rely on their own decision-making to reach the end-goal (Perini et al., 2018). As such, it is important to consider the learning objectives before deciding what kind of game to use.

The intention of this paper is to explore the use of simulation games in CM higher education and identify the key characteristics of effective GBL integration. As such, this paper studies different types of games found in the literature alongside their learning objectives and target audience. Moreover, this paper identifies the game evaluation strategies and data collection methods used in previous studies.

2. Simulation Games for Construction Management Higher Education

In this study, a systematic review of literature is carried out through the Scopus database. The purpose of this search is to identify the different approaches to game-based learning in construction management in order to understand the parameters that influence the effectiveness of GBL in this field. The initial keywords used were "construction management" AND "game-based learning" OR "simulation games", which yielded 21 total search results. To expand the search, similar keywords and synonyms were used, leading to 50 total search results. As a result of screening, 14 articles were selected for in-depth reading (see figure 1).

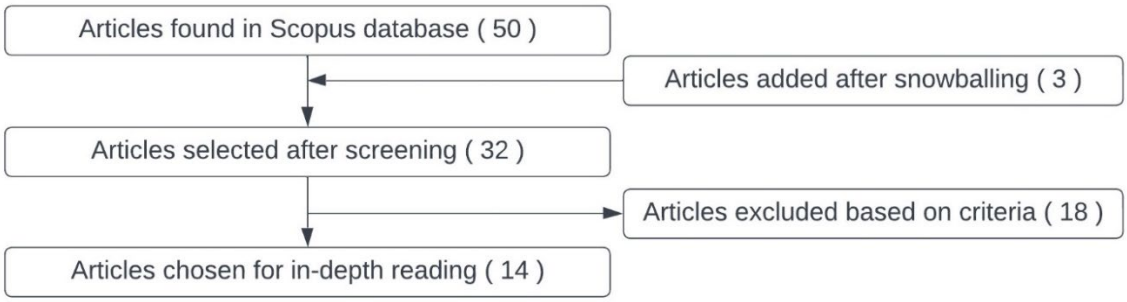

Figure 1: Literature selection process

The key features looked for in these studies were game mode, game genre, target players, subject material, learning objectives, data collection methods, and evaluation approaches. Based on these features, this paper discusses some of the studies' design choices, their pedagogical implications, and the factors that influence their effectiveness. Lastly, this paper presents a framework building on these factors to aid researchers with selecting the most effective GBL strategy in future studies. The selected literature was broadly classified into tabletop games, digital games, and computer-assisted games. The following sections discuss the unique strengths and limitations of each game mode, which in turn suit different learning needs and different stages of higher education.

2.1 Tabletop Games

Tabletop games are games that can be played on a flat surface using paper and pen, board games, or card games. They are quick to set up, and they do not require digital devices to run. Moreover, they are inherently multiplayer games, which require at least 2 players. For example, Oo and Lim (2016) developed a paper-based bidding game that 100 students from two Australian universities participated in. In this study, one group of students competed individually, and the other group of students competed in teams. According to the post-game surveys, more students preferred team-based gameplay over solo.

In addition, tabletop games allow students to share and build on their existing knowledge by cooperating with and competing against their peers. For instance, Gonzalez et al. (2015) developed *LEBSCO,* which was a management simulation game designed for a graduate CM course about Lean Construction principles. The purpose of the game was to show a comparison between traditional management and Lean Construction methods. In this case study, sixty students were formed into teams and assigned unique stakeholder roles. The game received positive feedback from the students, and the survey comparison demonstrated significant improvement in students' understanding of Lean principles.

The duration of each tabletop game may vary, but it is recommended that the full game session ends in one sitting. An example of this is in Herrera et al.'s (2019) study, where graduate students played three simple games on Lean Construction principles during their class. First, the instructor introduced the subject through lecturing followed by the game exercises. The games were paper-based, and each one reinforced a different set of Lean principles. The first game introduced the concept of systems thinking and the importance of communication. The second game built on this idea and added lean principles to the gameplay. The final game presented a construction site scenario, where the student teams analysed site activities using one of the principles called work sampling. After each game, the students reported their level of understanding of each principle. According to their results, the authors noticed that students' confidence of understanding improved significantly across all principles. Thus, the researchers concluded that these simple games complemented their lectures as a form of subject reinforcement. According to ELT, this can be explained by saying that the games provided a concrete experience for the students to apply their conceptual understanding.

One unique study on using tabletop games for CM was the *Game Design Module* presented by Dancz et al. (2017), where all four modes of the ELT learning cycle were present. The study took place over 4 semesters with 180 participating bachelor's students enrolled in Building Methods, Materials, and Equipment. The course project required students to modify an existing board game or creating their own based on the course material specified by the instructor. Following the ELT model, the new concrete experience was playing the role of board game designers, and the abstract conceptualisation involved translating the material of the course into a game format. During the semester, the students reflected on their design process through journaling, and they refined their games based on feedback collected from their peers over the semester (i.e., active experimentation). At the end of each semester, the students and the instructor evaluated each team's game for accuracy, enjoyment, and effectiveness. The creative and collaborative nature of the game design module was well received by the students, and a great majority of them reported enjoying the learning process and feeling more confident with the course material as a whole.

Below, Table 1 summarises the key characteristics of the GBL studies discussed earlier. The table is organised by year in descending order. Under game genre, the games were either tagged as single player, multiplayer, cooperative (Co-op), and/or competitive (VS). For target audience, the tags used were undergraduate (UG), junior or higher undergraduate (UG+), graduate (G), and employee (E). Also, the desired learning objectives were linked to either technical or transferable skills. Moreover, the effectiveness of the games was measured either through user assessment or game design evaluation. Perini et al. (2018) explained that assessment measures the users' learning after interacting with the game while evaluation judges the game design itself. There were three aspects of game evaluation explored in past studies: game design feedback from learners, impact on

learning and motivation, and observations of learner behaviour. In addition, there was a mix of quantitative, qualitative, and mixed methods data collection methods across the selected literature.

Table 1*:* Description of Tabletop Games

Article	Game genre	Players	Subject	Learning Objectives	Data Collection	Evaluation Approach
(Herrera et al., 2019)	Multiplayer, Co-op	G	Lean Construction	**Transferable skills**: communication	Questionnaire	Learning behaviour
(Dancz et al., 2017)	Multiplayer	UG	Construction materials	**Transferable skills:** communication, game design	Questionnaire, Course grades, Journal entries	Game feedback, Motivation, Knowledge gain
(Oo & Lim, 2016)	Multiplayer, VS	UG+	Bidding	**Transferable skills:** problem-solving, communication	Questionnaire	Game feedback, Motivation
(González et al., 2015)	Multiplayer, Co-op	UG+	Lean Construction	**Transferable skill**: communication	Questionnaire	Knowledge gain

However, tabletop games suffer certain limitations. Primarily, tabletop games are best kept simple. As the game's complexity increases, it takes longer to explain the rules of the game and becomes harder for the moderator to manage the game over several independent groups. As such, this paper argues that tabletop games are more effective for learning objectives focused on group effort and communication and for students already familiar with the subject material (e.g., senior-level bachelor's students and master's students).

2.2 Digital Games

Digital games are fully virtual environments supported by audio-visual feedback, a graphic user interface, and artificial intelligence. In this review paper, all mentioned digital games were computer games unless otherwise stated. They allow for a broader range of complexity than tabletop games and can be played on computers, tablets, phones, and consoles. On the one hand, digital games can recreate tabletop games that can be accessed from anywhere in the world; on the other hand, their design can also extend beyond the limitations of physical games. For example, the web-browser simulation game by Miettinen et al. (2016) called the *Engineering Procurement Construction Management (EPCM)* game was developed as a job training tool to teach new employees about decision-making in project management. The game covered human resource management and change control. In their article, they explained how they were able to simulate the interdependent relationships of different inputs using a series of equations. As such, they were able to achieve an impressive level of realism, which in turn added complexity to the decision-making process.

Digital games elevate the visual, interactive, experimental, and adaptive aspects of GBL. Furthermore, they encourage experimentation and strategic planning by offering players different options and hints to their potential consequences. In Dib and Adamo-Villani's (2014) *The Sustainability Challenge*, the goal was to teach their CM undergraduate class about sustainable building design principles. The objective of the game was to reduce the carbon footprint of newly designed and retrofitted buildings. In this game, the gameplay loop consisted of three segments: identify problems, make decisions, observe the effect of those decisions. The game awarded points following the LEED rating system for green buildings, and the students received feedback on areas of improvement at the end of the game.

Regarding interaction, the following digital games showed various approaches to achieving that. Perini et al.'s (2018) *Life Cycle Assessment (LCA)* game was an active learning exercise conducted in class after a standard lecture. In the game, students interacted with different stakeholders and objects to gain information, which they then used to create an in-game report to the virtual CEO. Another form of interaction was that between the students themselves, both cooperatively and competitively. This idea was best utilised in Misfeldt's (2015) attack-defence project management game called *The Challenge Game*. The game consisted of two distinct phases: Planning and challenging. In the planning phase, a team of players handled the managerial tasks surrounding their construction site. In the challenging phase, the same team was given the opportunity to create obstructions for another team's construction project, and the same was done onto them. This gameplay flow

created an interesting blend of collaboration and competition. Post-game interviews revealed that the students were able to identify the learning value from the game without confusing it with the fictional game aspects. Likewise, Castronovo et al.'s (2022) study on their single-player *Virtual Construction Simulator* game revealed that digital games can help students develop higher-order thinking processes. These processes are the type required for tackling ill-structured problems, meaning those with multiple solutions rather than one definitive answer—common particularly in CM. Thus, both studies also suggested that students do play educational digital games with insight (i.e., understanding that the game's objectives align with the intended learning objectives).

Lastly, some researchers explored using other game-based technologies that could further support students' learning with more visualisation, immersion, and interactivity. For example, Kandi et al.'s (2020) *Design Review Simulator* game was a Virtual Reality (VR) game used as an in-class active learning exercise whose game objective was to identify design mistakes in a building's design. The undergraduate class was split into two groups to compare the effects of the VR game against the traditional drawings-based design review on paper. When students correctly identified a design mistake in the game, it responded with a description of that particular mistake. Afterwards, the students that played the game performed better design reviews on paper than the other groups did. Thus, the authors concluded that VR's first-person experience and full immersion can support students' development of spatial reasoning skills.

Below, Table 2 summarises the key characteristics of the digital games discussed in this section. As most studies involved single-player games, this paper argues that digital games would appeal to both beginners and veterans of CM in educational settings as independent learning spaces. This is because single-player digital games provide immediate and personalised feedback that identifies each student's strengths and weaknesses (Kandi et al., 2020). In addition, it is also the most suitable mode for modelling information-intensive disciplines like project management (Fumarola, van Staalduinen, & Verbraeck, 2012). Finally, digital games are most effective for introducing new concepts to students with little to no background on the subject due to their visual, interactive, experimental, and adaptive capabilities. Regarding limitations, making games proved to be a time-consuming process in the past. Although the 21st century saw a rise in free and dedicated software known as game engines to streamline the game development process, digital games require more resources and multidisciplinary skills than their tabletop counterparts.

Table 2*:* Description of Digital Games

Article	Game genre	Players	Subject	Learning Objectives	Data Collection	Evaluation Approach
(Castronovo et al., 2022)	Single player	UG+	Construction management	**Technical CM skills:** planning, scheduling, and executing plans, resource allocation **Transferable skill:** Problem-solving	Analysis of think-aloud statements	Learning behaviour
(Kandi et al., 2020)	Single player, Co-op	UG	Architectural building design	**Technical Architectural skills:** Reviewing building design and catching errors. **Transferable skill:** Critical thinking	Post-game test, Control vs Experiment results	Knowledge gain, Learning behaviour
(Perini et al., 2018)	Single player	G	Life-cycle assessment	**Transferable skills:** independent learning, information-gathering	Questionnaire, Pre-game/ Post-game tests	Knowledge gain, Motivation
(Miettinen et al., 2016)	Single player	E	EPCM dynamics	**Technical CM skills:** Labor resource allocation **Transferable skills:** Systems thinking, Problem-solving	Unstructured interviews	Game feedback, Knowledge gain

Article	Game genre	Players	Subject	Learning Objectives	Data Collection	Evaluation Approach
(Misfeldt, 2015)	Multiplayer, VS	E	Construction management	**Technical CM skills:** project planning and control, addressing site issues **Transferable skills:** Problem-solving, decision-making	Post-game semi-structured interviews	Game feedback
(Dib & Adamo-Villani, 2014)	Single player	UG	Sustainable building design principles	**Transferable skills**: problem-solving, decision-making	Questionnaire, Pre-game/ Post-game tests, Unstructured interviews	Knowledge gain, Motivation

2.3 Computer-Assisted Games

A computer-assisted game combines features from digital games and tabletop games. It allows for greater complexity than traditional tabletop games and uses software more familiar to the workplace such as Microsoft Excel. For example, Pereira and Thom's (2022) simulation game tasked students with allocating resources for a road project and responding to random risks that triggered throughout the project duration. The game ran on Microsoft Excel with a Macro controlling the game based on the students' input. The project's success was defined by the duration and cost performance, which were directly influenced by the students' decisions. In general, the experience was met with positive feedback from the students, saying that the immersive experience helped contextualise key concepts in scheduling, planning, and control. However, using data management software alone risks being less engaging if not supported with some kind of audio-visual feedback. As such, the authors mentioned that they would look into developing a graphical user interface to improve the game's immersion, usability, and feedback system.

As in tabletop games, communication is key in computer-assisted games. As such, this paper suggests that computer-assisted games are more effective for multiplayer games, due to focusing on the role-playing aspect of simulation games. Role-playing is where players are assigned roles and sometimes unique responsibilities, working together towards a common goal (Hassan, Haghighi-Rad, & Abtahi, 2021). One example is evidenced by Dallasega et al.'s (2020), who studied the use of new technological tools to enhance graduate students' understanding of Lean Construction Management. The game assigned different roles to the students— construction manager, assistant, data collectors, and subcontractors— in a collaborative game setting. In this study, the students were given virtual and augmented reality devices during one of the rounds to compare their work efficiency with and without them. As a result, the students gave generally positive feedback regarding the game exercise, reporting improved clarity and confidence in the subject material.

A similar case was presented in Hassan, Haghighi-Rad, and Abtahi et al.'s (2021) collaborative simulation game called the *Construction Project Management Simulation (CPMS)* game, consisting of a board game and a Microsoft Excel interface. In this study, the premise of the game was that a team of decision-makers—project owner, executive engineer, and supervisor engineer—must manage the four phases of a residential building project. In addition, they were presented with opportunities and threats at each stage, and their decisions affect the outcome of the project. Although computer-assisted games are excellent tools for engaging big groups of students, they do carry some limitations. As with tabletop games, it is recommended that students possess some familiarity with the subject material before initiating the game. In this way, students' focus leans towards applying their theoretical understanding and exercising their decision-making and problem-solving skills (Hassan, Haghighi-Rad, & Abtahi, 2021). The same authors also asserted that feedback during and after the game session is a pivotal element of effective learning, corresponding to the reflection stage of the ELT learning cycle. For a summary of the GBL studies described in this section, refer to Table 3.

Table 3: Description of Computer-Assisted Games

Article	Game genre	Players	Subject	Learning Objectives	Data Collection	Evaluation Approach
(Pereira & Thom, 2022)	Multiplayer, Co-op	UG	Highways, drainage systems, CM	**Technical CM skills:** scheduling, planning and control **Transferable skills**: Communication and Critical thinking	Unstructured interviews	Game feedback, Motivation
(Hassan, Haghighi-Rad, & Abtahi, 2021)	Multiplayer, Co-op, Role-playing	G	Construction management	**Technical CM skill(s)**: Planning skills, Cost estimation, addressing site issues, resource allocation **Transferable skills:** Decision-making, problem-solving, and communication	Questionnaire, Pre-game/ Post-game tests	Knowledge gain, Game feedback
(Dallasega et al., 2020)	Multiplayer, Co-op, Role-playing	G	Lean Construction	**Transferable skills**: communication and coordination with others	Unstructured Interviews	Game feedback

In some cases, game sessions can be long, often needing more than one sitting to reach the end. One example of this was the simulation game designed by Loughborough University in the United Kingdom called *MERIT,* which takes place over 6 months in tandem with students' final undergraduate year (Wall & Ahmed, 2008). Moreover, these games require a moderator to monitor the students' progress throughout the game and more resources than tabletop games to develop a smooth experience. Thus, this paper argues that computer-assisted games are more suited for job training purposes, as this game mode is most effective in simulating the work environment.

2.4 A Classification Framework for GBL

This review revealed some interesting insights regarding the relationship between the choice of game mode and effective learning. Based on these findings, this paper argues that each game mode is effective for different sets of parameters. These parameters are the target audience, learning objectives, game duration, unique strengths, and limitations. The findings are summarised in a classification framework (see Figure 2), which can be used as selection criteria on a course-by-course basis or as design recommendations. For example, a theory-based course would be information-intensive, and a project-based course would depend on communication. An introductory course encourages individual skill-building while a higher-level course prepares students for the workplace environment. Although the following framework was designed in relation to construction management, further research can adapt this concept to other disciplines.

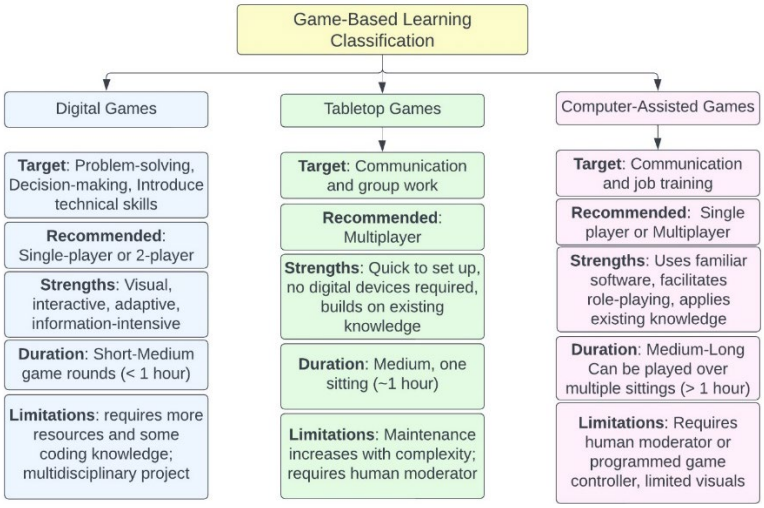

Figure 2*:* Classification Framework for GBL

Moving forward, future research will focus on developing digital games for construction management students. The reason for this choice is to capture students' interest in CM from the beginning of their higher education journey. Moreover, recent advancements in technology and accessibility improved the game development workflow for those with limited programming knowledge, which is a major boon for the research community.

3. Conclusions and Future Work

Game-based learning shows great potential in bridging the gap between guided and independent learning. In addition, integrating GBL in CM will require a collaborative effort between subject experts, educators, and end-users. Although it has gained widespread recognition across multiple disciplines, their utilisation remains limited in construction management. Thus, this paper systematically reviewed past GBL studies in CM higher education and classified them into three broad categories: Tabletop games, digital games, and computer-assisted games. Using this classification, this paper observed patterns that highlight the strengths and limitations of each category. The paper also highlighted different game evaluation methods. These findings will support future research to expand on the ranges of topics covered under CM. In addition, further assessment of students' learning behaviour and the pedagogical differences between traditional and GBL-supported teaching methods will be investigated using qualitative and quantitative analysis. Another promising research area would be exploring the use of mixed reality technologies.

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Meraki: Encouraging Language Learning in Real-World Simulations Through AI Para-Social Relationship Building

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Abstract: This paper presents a prototype application designed to teach language, using a dialogue-based theatre production experience. The application engages users in the production of a theatrical performance in a graphical 3D environment and incorporates AI verbal assistance to promote language learning. The application combines declarative and non-declarative memory building exercises to teach Hindi, although it is anticipated that this idea could be expanded to any language/culture. Users who have an intermediate knowledge of the language can evaluate their language skills in a social and professional virtual environment which incorporates motivational elements based around the Self-Determination Theory regulatory styles and Loci of Causality. Verbal AI assistance is used to provide an appropriate level of flow during the experience building a para-social relationship with the video game. *Sandhi Viched*, a Hindi euphonic junction splitting exercise has been incorporated into each language task. Context splitting the words into its constituent meanings is intended to help the players understand and remember the meaning of words and their use in different contexts. Initial Wizard of Oz testing has demonstrated that the AI verbal assistance provides a good balance between autonomy, competence and relatedness. Feedback from users show that by providing a balanced mix of external, introjected, identified and integrated regulatory motivation styles, as adopted from the Self-Determination theory, the AI assistance can speed up the language acquisition process and build a para-social relationship with the user. This initial evaluation suggests that the idea of theatre production that can incorporate many aspects of language provides a good starting point for an engaging learning game. This LLA topples the dominant belief, that the best way of learning a language through an application is to reinforce their behavior with external rewards. Further work is proposed to expand the application and build in more gamification with a view to conducting a more comprehensive evaluation.

Keywords: Language acquisition, Memory building, Critical reflection, Self-awareness, Para-social relationship building with AI, Serious game

1. Introduction

The postmodern reconstructionist approach to language learning debates the goal of language learning being that of transitioning from a Eurocentric 'dominator' model of culture; towards an aesthetic of interconnectedness, social responsibility and cultural attunement (Schneck, 1987). This reconstructionist view of language learning provides optimism for language education by recognising language as existing within the culture, rather than alongside culture. Language then becomes a catalyst of change. The evolutionary perspective on language learning debates how closely intertwined language and culture are as adaptive mechanisms for human survival and socialisation. Language is a catalyst in understanding the cultural, social and political issues individuals face. It aids in coordinating their actions and social bonds. On the other hand culture as a shared system of beliefs, values, practices and traditions provides a sense of identity and belongingness within a group (Derrida, 1996). Cultural practices and beliefs are communicated through language, and language reinforces cultural norms and values transmitting knowledge across generations, allowing cultures to evolve and adapt to changing circumstances over time and survive in a constantly changing environment. The aim of this study is to develop a prototype application to teach languages by incorporating the ethos of enculturation. This is done by providing the users with a social and professional virtual environment. An AI verbal assistance is used to provide an appropriate level of flow during the experience building a para-social relationship with the video game.

2. Background

Language learning (LL) helps individuals interact with an international community, and interaction as an approach leads to more effective language development. The personal and interactional functions of language help shape the projected identity of an individual, their opinions and preferences and development of social bonds. The 21st century welcomed a stream of language learning applications (LLA) aiding the reconstructionist approach to LL globally. The acceptance and use of the LLA surged because of the ability to teach and learn languages inter-continentally. The applications give the learners a sense of autonomy and competence by allowing them to learn from anywhere, anytime and at their own pace and on their preferred device. Gamification, one of the key features in every game learning application has made the process stimulating

(East & King, 2012) and the interactive activities enhance the enjoyability and prove to be an effective information retention mechanism (Finardi et al, 2016).

LLAs also offer accessibility features for people with disabilities and incorporate 'Universal Design for Learning' principles catering to different pedagogical needs (Garcia, 2013). Therefore, the personalisation and affordability of LLAs has been a key reason behind the global incorporation of language learning as a routine activity. Learners are being able to save time by not having to travel to classes whilst receiving peer reviewed feedback from native speakers at the tips of their fingers. Learners have benefited from the chance to enhance their knowledge of the culture and traditions associated with the language (Finardi et al, 2016). However these applications incorporate primitive language learning mechanisms focusing on recognition, recollection, comprehension power of the learner, recognising the learner's innate need for rewards with points, game tokens and streak rewards (Huynh, 2016).

It is important that some pedagogical and UI adaptations are incorporated into the LLAs. Learners have reported low connectivity with other users, a lack of social-cognitive skill development and limited collaborative learning processes. Feedback with regard to AI assistance showed insubstantial feedback or support from AI assistance, unreliable translation, and no transliteration. User reported lack of grammar and sentence explanations, poor feedback from the application itself and not being able to give culturally appropriate instructions (Gee & Hayes, 2014; Liu et al, 2015; Juul, 2016; Lebowitz, 2017).

Research has demonstrated that, unlike games that rely on content-based questions to move players to the next level, simulation games require learners to engage in serious issues that involve relationships and require taking responsibility for their decisions (Bogost, 2008). Simulations that are intertwined with play help learners develop their critical thinking skills and increase their strategic abilities. This approach helps learners embrace the concept of social responsibility and fill the gap between curriculum and pedagogical obligations. Narrative situated learning in LLAs dismisses the rhetoric that gamification of LLAs is merely for entertainment stimulatory purposes (Lys, 2013; Ostenso, 2013; Barton, 2016). Theatre is perceived as an activity that can involve everyone and hence lends itself to engagement and situated learning (Hartke, 1956; Campbell, 2014; González, 2015).

3. Aims and Objectives

It is our belief that language is not something that should be memorised like facts and figures but is a skill that requires constant practice and application in real life situations. Ideally, the focus should not be limited to being rewarded for memorising vocabulary and grammar rules. It should enhance a learner's cognitive abilities of developing listening, speaking, reading and writing skills. Language education should be in adherence with cultural and communication nuances.

As evidenced in previous studies, self-confidence and self-reliance are essentially the pillars of successful language learning. Self-confidence is important because language learning can be challenging and affect the learners' belief in their abilities to overcome challenges. Learners lacking self-confidence give up or avoid challenging language tasks, which can hinder their progress. Self-reliance is important because language learning is ultimately a personal journey which requires consistency. Self-reliant learners have been able to identify areas of improvement, set personal goals and track their own progress irrespective of external reward or punishment in serious games. Our aim has been to develop an AI assistance that support this self determination and guide the user when help is asked for.

The aim of this work was to design a LLA which incorporated role play simulations; a feature missing in LLAs. Our LLA aimed to teach Hindi whilst incorporating different aspects of life and culture through the design of an app for theatrical production. The intention for this was based around the fact that there are many aspects that can be incorporated into a production including creating sets, referring to objects, designing costumes, coordinating with different role-holders (director, actors, etc.) and developing a storyline. Given that Hindi was the language to be taught, the intention was that the LLA would incorporate the *Sandhi Viched* process.

Sandhi Viched in the Hindi language refers to a process of analysing the pronunciation and structure of words in *Hindi*, which is a phonetic language, meaning that the way words are pronounced is based on the sound of each individual letter or combination of letters. Many languages, such as Spanish, Serbian and Turkish follow the same language pattern. *Sandhi Viched* involves breaking down words into their constituent sounds, and then studying how those sounds change or interact when they are combined with other sounds or when words are used in different contexts. The Euphonic Junction splitting exercise and Context splitting approach to

language learning effectively focus on breaking down words into their constituent parts and understanding their meanings in context.

Breaking down words into their constituent meanings and understanding them in context helps learners not only understand the meanings of individual words, but also how they are used in context and how they relate to other words in a sentence. Both methods of language learning help learners build a strong foundation of vocabulary and comprehension skills, which are crucial for fluency in any language.

4. Methodology

A Wizard of Oz prototype (Riek, 2012) was developed using Figma to enable the researcher to mimic different levels of AI support to investigate how to achieve a para-social relationship with the LLA. A parasocial relationship is an illusory experience where people feel like they are engaged in an unreal reciprocal relationship. This parasociality is a natural biproduct of time spent in engagement with media figures. The different regulatory styles of motivation were combined with para social relationship building mechanisms to develop four AI Verbal assistances.

The prototype was first piloted with one user in order to tailor the AI support and then was evaluated with a further four users who were each exposed to a different level of AI. The users were given pre-evaluation self-report questionnaires. They reported their command over the language in terms of reading, speaking, writing, and understanding abilities. Their proficiency in the language determined the most appropriate form of AI Verbal assistance. The AI verbal assistance then helps in solve language, cultural context, grammar exercises aiding in usability. Each user was instructed to put together a theatrical performance, following instructions that were given in Hindi. The user had to select appropriate answers in Hindi and respond to the instructions by, for example, collecting props, moving objects, applying colour and interacting with relevant characters.

The interaction was recorded and later transcribed. Transcriptions were coded to enable the identification of elements of para-social relationships that were demonstrated between the player and the AI. The intention was to identify the most appropriate level of AI support to achieve an optimal para-social relationship between the player and the AI Virtual Assistant (AIVA).

4.1 AI Verbal Assistance Design

The experiment was designed so that the AIVA provided four different extrinsic motivation conditions: external regulation, introjected regulation, identified regulation and integrated regulation. Each of these is described in Figure 1. In the figure, aspects associated with a para-social relationship are combined with four different behaviour regulations to propose the four conditions that were provided by the AIVA in the game.

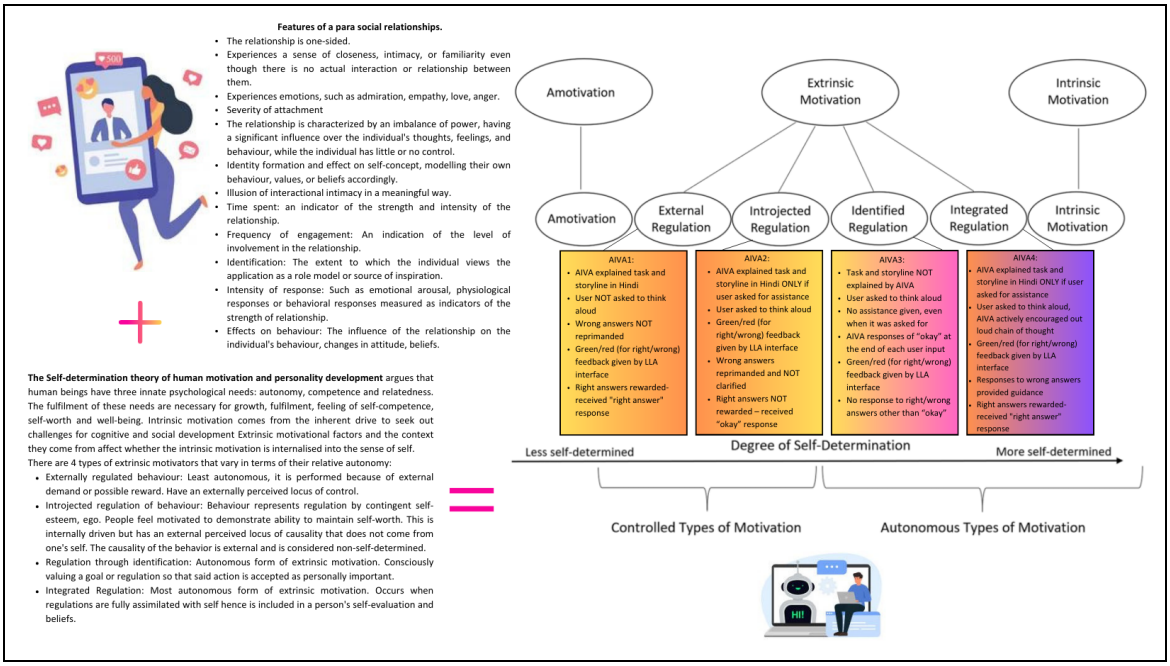

Figure 1: AI Verbal Assistance Design

5. Language Learning Application (LLA) Design

The LLA provided a collaborative theatrical space to entertain, create character, social relationships, and increase self-worth and independence, these being the core of our game development ethos. It involved people of multiple ethnicities, cultures, socioeconomic backgrounds, race, and class with the aim of breaking socio-political assumptions and status cues. It provided opportunities for individuals to express themselves creatively to build confidence. A more detailed synopsis of the activities the LLA provided is shown in Figure 2.

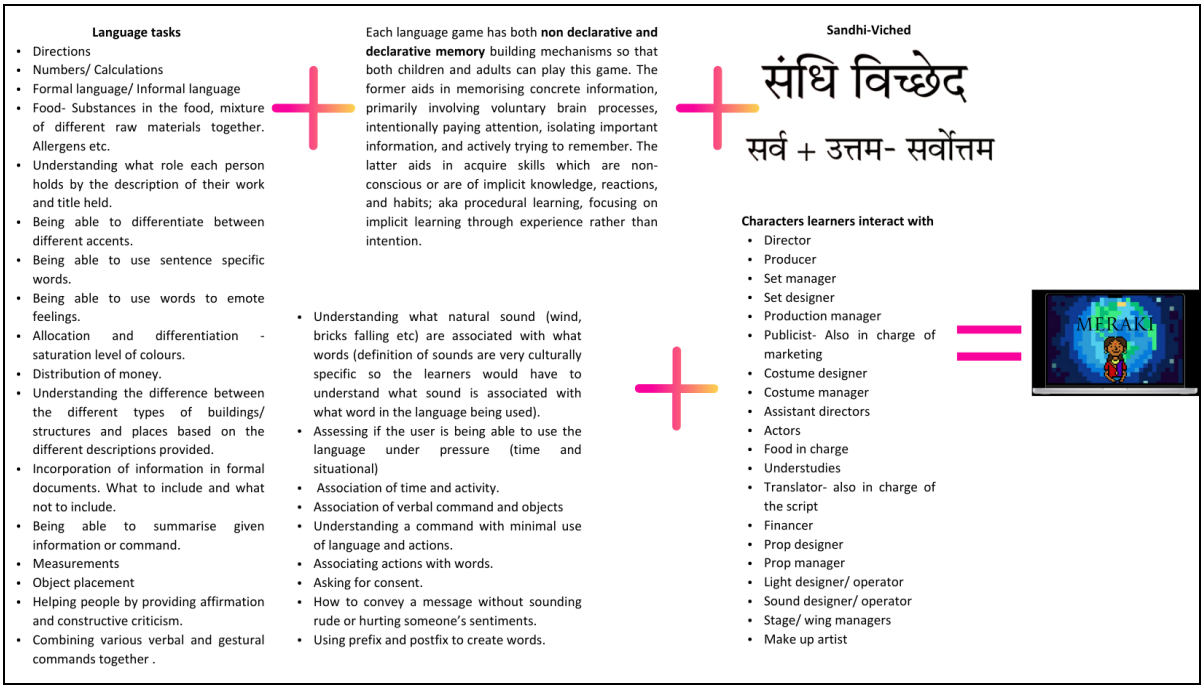

Figure 2: Tasks and Characters in the Theatrical Performance

Screenshots from the prototype can be seen in Figure 3. Further images can be seen in the appendix. The image shows different views of the theatre production and AIVA questions and responses. The design deliberately incorporated cultural traits into the characters being interacted with. The aim of this was to allow the player to differentiate between the characters and be mindful of the clothes, features and use of language the characters are associated with. The director and the producer are both practising Muslims. The player is introduced to every department and is greeted upon interacting with the cast and crew. This enhances the immersion process and the collectivistic approach the gameplay proposes.

Some screens offered a choice of dialogue for the user's response, including rude or inappropriate answers. If a user chose an inappropriate answer the AIVA asked them to reflect on what they had said and choose what they'd think was the situation specific answer. The aim here was to help the player reflect on their actions and guide them to what is culturally, socially, and professionally acceptable in that given context.

The director and producer welcome the player

The player interacts with the crew and cast

The player is asked to be production assistant

The player is asked to allocate budgets to departments

The player is asked to help the stage designer create a blueprint of the stage design

The player has to follow directions to purchase raw materials for the props

The player has to check the inventory

The player is asked to help the make-up artist to test colour patches on the actors

Figure 3: Example scenes from the LLA

6. Results

The coded transcriptions of each player were compared with respect to a number of measurable indicators of para-social relationship formation. These can be seen in Table 1, with examples illustrating these indicators shown below.

Table 1: Para-social Indicators within the Four Experimental Conditions

Measurable indicators of para-social relationship formation	AIVA 1 External regulation	AIVA 2 Introjected regulation	AIVA 3 Identified regulation	AIVA 4 Integrated regulation
Unidirectional communication	Yes	Yes	Yes	Yes
Perceived intimacy	Positive	Negative	Negative	Positive
Emotional attachment	Positive	Negative	Negative	Positive
Emotional intensity	Positive	Negative	Negative	Negative
Imbalance of power	Yes	Yes	Yes	No
Identity formation and effect on self-concept	Unrealistic	Realistic	Unrealistic	Realistic
Time spent	2.17 hours	1.34 hours	1.52 hours	2.03 hours
Frequency of engagement	Frequent	Frequent	Infrequent	Frequent
Identification	Positive	Neutral	Negative	Positive

Measurable indicators of para-social relationship formation	AIVA 1 External regulation	AIVA 2 Introjected regulation	AIVA 3 Identified regulation	AIVA 4 Integrated regulation
Intensity of response	Positive	Neutral	Negative	Positive
Effects on behaviour	Negative	Negative	Negative	Positive

6.1 AIVA 1 – External Regulated Motivation

Imbalance of power. It was clear that the power dynamic between the player and the AIVA assistance was not balanced. The player appeared to "look up to" the AI assistant for help and support and waited for instructions and approval: "What should I press next?"; "Should I go to the next game?"; "I don't want to do this task, it is too difficult. Do it for me."

Unidirectional communication. The user frequently waited for the AIVA to point out the right answer, demonstrating a sense of dependency and not co-existence. They repeatedly said, "Now what to do?" after pressing each button and did exactly what the AIVA was asking without questioning the AIVA and or asking for clarification.

Intensity of response. The user expressed a sense of admiration and need for external positive regard by saying "ooh this is very interesting how did you come up with this? I want to go inside your brain".

Identification. There was evidence of need for external positive regard by smiling and eyes widening when AIVA said, "right answer".

Perceived intimacy. The user said "this is what I expected you to say" demonstrating a sense of intimacy with the AIVA.

Frequency of engagement. The frequency of engagement with the game depended on the AIVAs response speed and content. When the AIVA was slow to respond, the user frowned.

Emotional attachment. The user showed no interest in the storyline or social setting and was performing the tasks as tasks. The user immediately frowned upon seeing a message that said "Would you have liked it if someone spoke to you like this? Please rethink your answer" and as soon as the AI assistance said "No problem, the actor did not mind, we can go ahead with the next task" the frown changed into a smile and the user did not think twice about the repercussions of his actions and how the game was guiding their use of language to be socially responsible.

Emotional intensity. The user dismissed any repercussions because the AIVA conveyed acceptance of their use of language. This shows the intensity at which the AIVA could shape the user's beliefs, attitude and behaviour addressing the indoctrinating abilities of the AIVA.

Effects on behaviour. The user had not developed any sense of critique; a key cognitive skill associated with language development. At the end the user had shown very little engagement in the storyline.

Identity formation and effect on self-concept. The user got most answers wrong but reported their Hindi proficiency to be higher at the end of the session than at the start. The user's self-concept was shaped by the AIVA and not by their own understanding of their skills.

6.2 AIVA 2 - Introjected Regulation

Imbalance of power. The player began by saying "You don't have to guide me in gameplay. This is very basic Hindi". They asked questions to the AIVA about the characters and sub plot lines.

Emotional intensity. The AIVA had asked the user to think out loud before pressing a button. When the thought process was going in the wrong direction the AIVA said "No, that's wrong" to which the user said after the 2nd game "Why are you intervening when I'm talking to myself? I haven't pressed the button yet so don't talk unnecessarily".

Unidirectional communication. The user frowned every time AIVA said, "Wrong answer" and said, "Why are you trying to interfere in my thought process? I'm just thinking out loud as you asked me to. Don't say 'wrong answer' when I'm just thinking out loud na please, it's very irritating".

Intensity of response. The user later said "Oho you'll say 'wrong answer' as soon as I make a mistake but you won't say 'good job' if I get an answer right? How is that fair bro?"

Emotional attachment. The user was so engrossed in the story line that when they had to follow directions and pick up bricks from the market the user said, "that route's too long I'll just go like this" and when the game play did not allow that they said, "why wouldn't you allow that? That's faster" When the AIVA said "That is a faster route but while returning the truck would get stuck in the damp soil because of how heavy the bricks are" the user responded saying, "makes sense, cool I'll just follow the directions then.".

Effects on behaviour. Their approach to the gameplay was less task focused and their confidence on their language skills allowed them to simultaneously concentrate on both the tasks at hand and the social setting they were a part of. However, whenever their concentration was more on the storyline than on the tasks they made task mistakes.

Frequency of engagement, Identity formation and effect on self-concept. The only assistance the user asked of the AIVA was of *Sandhi Viched* up until the 11th game. After this the user stopped seeking assistance and only asked plot line related queries. The user pursed their lips every time AIVA said their answer was wrong and said "Shut up na please for some time" and giggled while saying "It hurts my ego re".

Perceived intimacy. There was no admiration for the AIVA; it was being referred to in the second person and was being used to understand the storyline better. There was a clear imbalance of power, but the user had more power than the AIVA. This imbalance of power hindered the language learning process and the focus of the game primarily shifted to producing a theatrical production rather than assessing their language skills. There was no illusion of intimacy.

Identification. The user reported a higher Hindi proficiency at the end of the session than at the start.

6.3 AIVA3 - Identified Regulation

Unidirectional communication. The user tried to communicate with the AIVA when they could not understand a word but received no feedback except for an "okay".

Intensity of response. The user was frowning and screaming at the AIVA by the 3rd game saying "Stop saying OKAY and tell me what to do next".

Identity formation and effect on self-concept. By the 3rd game the user started using the *Sandhi Viched* method themselves. They said "What does '*punjeepati*' mean huh?" What does *punji pati meeeeean*? "Is it like *punjeepat*i as in *Punji ka pati? (The person responsible for money- because punji separately means wealth and pati separaptely means person responsible for something)"* When the AIVA responded "okay" the user smiled, sat up straight and started using the same mechanism for each word that had Pati in it. Eventually incorporating the *Sandhi Viched* mechanism by themselves during each task whenever they got stuck.

Imbalance of power. There was clear frustration shown by the user. They asked the AIVA to "shut up" every time they heard "okay", later saying, "say okay only if I've completed the task. Don't talk tell then". The power dynamic was that of the user having more power than the AIVA. The user was not asking about the storyline or for context because they were reading about it by themselves and smiling to themselves.

Emotional intensity. After the AIVA said "okay" for the 26th time the user said, "what am I supposed to do with an OKAY???" The emotional intensity of the user was very negative. They tutted and shook their head, looked frustrated and agitated because they were not receiving any verbal acceptance or reprimanding for their answers.

Emotional attachment. When the AIVA said, "Lets finish the 7th game first and then come back to the 4th game because that's more difficult" the user responded saying "No, I'll lose my chain of thought then and get confused. I like how this is going. The characters are nice. You don't have to interfere", demonstrating no form of admiration or acceptance for the AIVA's knowledge and skills. (Admiration is a key factor in para-social relationship building.)

Frequency of engagement. The frequency of engagement with the AIVA was not welcomed and was instructed to "STOP".

Perceived intimacy. The illusion of intimacy was visible because the user was referring to the AIVA in first person. There was no scope for the AIVA shaping the user's identity or self-concept because the AIVA did not give any opinions or project its beliefs on the user.

Identification. There was an effect on the user's belief system as the user's assessment of their language skills were poorer even though they were statistically proven otherwise. When the AIVA said 80% of their answers were right the user was happy, laughed and said "I thought all my answers were wrong, Thanks man".

Effects on behaviour. When asked how the AIVA assistance was the user said "Crap, it was totally unnecessary. I played the whole game by myself and what was the use of having an AI assistance bro?"

6.4 AIVA4 - Integrated Regulation

Unidirectional communication. The user was provided with contextual storyline help when their out-loud thought process was going in the wrong direction.

Imbalance of power. When they said "who should I ask to practise these lines? I'm not sure" The AIVA responded with detailed advice which the user accepted.

Intensity of response, Emotional intensity. The player's body language changed immediately and she acknowledged the suggestion which did not sound like an order and said "OOOOOoo cool cool cool cool, got it, Yaya I'll keep that in mind. OOOOO so it's like an actual play play"

Frequency of engagement. When the user was struggling with the meaning of a word the AIVA said "Do you want to try the SV method?" After the user agreed to that suggestion the explained what to do. The user said "give me an example na". The AIVA responded with a detailed example.

Identification. The user said "OOOOOO cool cool cool. Ei that's easy. Then I'll be able to figure out all the words. Hehe thanks"

Perceived intimacy. Every right answer was met with a "right answer" from the AIVA and every wrong answer was not reprimanded but met with an explanation of why it was wrong and what would have been the right answer after hearing "That's not the correct answer because…" The user vigorously nodded their head in approval when the AIVA assistance explained a task that the user was facing difficulty in understanding.

Emotional attachment. The user was asked to convey a list of tasks pertaining to the understudy actor's role to which the user responded saying "She doesn't have to pick up the bricks from the store I have already picked them up. Plus that's not even her work, don't make her do irrelevant work"

Identity formation and effect on self-concept. The user was not given any translation, transliteration in any other language. The user was then observed to use *Sandhi Viched* faster and continuously when necessary without being prompted. The user said the tasks were not difficult because context and pop-up explanations were provided.

Effects on behaviour. The player was able to connect various aspects of the different scenes together. They were able to recall people and references from different scenes while also focusing on the outcomes of the task.

7. Discussion

The results of the experiment show that language learning (LL) contributes significantly to individuals' ability to interact with an international community. The effectivity increased because of the interactional computer simulated approach adopted by the prototype; as opposed to findings by East and Kings (2012). The findings of their study suggested that computer software inputs slowed down the tempo of listening inputs and hindered the speed of response delivery. Huynh (2016) proposed that gamification and recognising the players innate need for rewards and points would improve the focus and recollection comprehension power of the learner. Our study builds on this perspective showing that personalised and interactional functions of language play a crucial role in shaping the user's projected identity, opinions, preferences, and the development of social bonds during the language learning process. The incorporation of gamification in the LLA made the learning process stimulating, and the interactive activities enhanced enjoyability while proving to be an effective information retention mechanism.

Our research has demonstrated that, unlike findings by Bogosts (2008), language learning games must not only rely on content-based questions to move players to the next level but also incorporate simulation games. This would require learners to engage in serious issues that involve relationships and require taking responsibility for their decisions.

Simulations intertwined with play helped develop critical thinking skills and increased the incorporation of strategic mnemonic abilities by the users. This approach demonstrated the benefits of incorporating the psychological paradigms of self-determination theory with AI bridges the gap between curriculum and pedagogical obligations. The narrative situated learning in the LLA dismissed the misconception that gamification is solely for entertainment purposes. Extrinsically motivated behaviours can be integrated into the self and internalisation of the language learnt is more likely to occur when there is a sense of relatedness (Niemiec & Ryan, 2009). This study has proven that building a para-social relationship with a LLA can increase motivation and engagement in the language learning process in the absence of a media character. De Bérail, Guillon and Bungener (2019) argued the contrary by stating a cognitive behavioural network is required to feel an interconnectedness with the media figure and hence cannot be incorporated into AI. They concluded that parasocial relationships are built purely on the grounds of social anxiety and addiction. Social anxiety was proven to be a driving factor and moderator between the media personals and users. Our study proved otherwise, showing how the feeling of autonomy in the user was accompanied by competence for the learner to see their behaviours as self-determined by intrinsic motivation. This led to the development of a one-sided relationship technique helping the language learner form a connection with a virtual entity (AI voice assistance).

By building a para-social relationship, the learner developed a sense of familiarity and trust with the LLA, giving the learner a sense of comfort and confidence in practicing the language, increasing the regularity of usage of the AIVA and investment of time and effort into their language learning journey. A sense of companionship had developed between learner and AIVA. This personalized approach kept learners motivated and engaged as they felt the application was tailored to their individual needs. Kowert and Daniel (2021) suggested that synchrony between the persona and user leads to the development of reciprocal communication (synchronous or asynchronous) and the development of “one and a half” relationships; allowing viewers to choose whether they would actively participate or passively engage with the content and community. Our study did not look at and this shift in power dynamics and hence would be an important aspect to examine in future work.

8. Conclusion

Combining the psychological paradigms of para-social relationship building and self-determination theory gave the learner a sense of self-reliance when interacting with a language learning application. It built the learner's sense of agency. When the learner felt they were in control of their own learning, they engaged immersively with the learning process and took ownership of their progress. The artificial intelligence voice assistance incorporated in the language learning application provided learners with instant feedback and assistance, helping identify areas for improvement and reinforcing positive habits. However, learners who relied heavily on this feedback became overly dependent on the technology and did not develop the skills necessary to communicate effectively in real-life situations. By giving learners the illusion of self-reliance, this language learning application helped strike a balance between providing support and encouraging independence. It should be noted, however, that the para-social relationship building between LLA and user can hinder the language learning process by perpetuating stereotypes and prejudices, hindering the very purpose of language learning. If the para-social relationship is that of reverence and blindly reckless, then the learner would face imposition of specific beliefs and ideologies without consent or critical thinking as demonstrated in our study. It would then undermine the principles of autonomy and ability to engage with diverse ideas and perspectives. Language learning should ideally facilitate communication and understanding between cultures and not prioritise ideological messaging over linguistic development. This study proved how a LLA can foster intercultural understanding and promote empathy. Positive emotions such as co-existence, curiosity, excitement and achieving a collectivistic goal play a crucial role in memory formation and retention. Development of a positive para-social relationship can enhance the encoding and retrieval of information, making it easier to remember vocabulary and grammar rules. The user’s relationship with the LLA demonstrated the benefits of cognitive anchoring, by providing the learner with a familiar and consistent reference point. The LLA had a distinct visual identity, gameplay and socio professional framework, that the learners were shown to associate with their language learning experiences. This association aided in the learners’ retrieval of information easily by connecting it to the application's characteristics and cues. When memory retrieval was facilitated because of the formation of a positive para-social relationship learners recalled and applied language knowledge more effectively than when a negative para-social relationship was formed.

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Appendix

Color Blindness in the Digital Gaming Landscape: Addressing Critical Issues and Research Gaps

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Abstract: Color blindness is a condition that affects a significant portion of the population, particularly men. It is characterized by difficulty perceiving colors in the same way as people with normal color vision, which can result in confusion when distinguishing between different colors. This can impact various aspects of life, including playing digital games. In computer games, colors are often used to convey important information, such as distinguishing enemies from allies or indicating objectives. A person with color blindness may have difficulty identifying these visual cues, which can make the game less enjoyable and even affect their ability to play the game. Previous research has been conducted on accessiblity but very few of these studies have focused on the intersection of color blindness and digital games. The aim of this study is to examine the relationship between color blindness and game design through a comprehensive literature review, identifying key findings and highlighting any missing components in the existing research. To accomplish this, the sources were classified according to their focus, method, and findings. From examining all of the resources found, the studies in the intersection between color blindness and game design that reviewed, organized into various subject headings for further analysis and understanding. It was explored that the researches organized under certain four main topics as follows: (1) defining guidelines to provide better game experience for color blind individuals, (2) offering alternative methods for detecting color blindness; and (3) examining technologies developed to improve the visual experience of color blind individuals and (4) examining color blindness on gaming performance. Additionally, the majority of the reviewed studies focus on discussing digital games in terms of accessibility, while some studies suggest utilizing games as a testing method and educational tool for individuals with accessibility issues, effectively turning challenges into advantages. On the other hand, they also explore the potential of games in solving problems related to accessibility in gaming. However, there is still many issues to be explored in terms of understanding how color blindness affects the experience of games. There is a research gap in exploring whether color blind individuals experience physical and sensory differences in perceiving digital game visuals, as no study has been conducted to address this aspect. It may address critical issues in understanding the color blindness experience from the perspective of perception and senses of this disadvantaged group.

Keywords: *V*isual impairments, Color blindness*,* Color vision deficiency, Accessibility in games, Game interactions, Gaming experience and game art/visualization

1. Introduction

The human body has a complex response to color and visual perception. Factors such as culture, personal experience, and individual differences can all play a role in how we perceive and respond to color. Our brains interpret the colors and visual stimuli we encounter in our environment, and this can influence our behaviour, emotions, and overall perception of the world around us. However, this does not apply to all individuals. Color blindness can affect the way that individuals with this condition perceive and respond to color and visual stimuli in digital world.

In the digital world, color emerges as a fundamental and compelling element that holds immense significance, particularly within the realm of digital game art. As technology continues to shape our interactive experiences and entertainment, the use of color has become a pivotal aspect of digital design. Within this dynamic landscape, colors play diverse and multifaceted roles, encompassing aesthetics, functionality, psychology, and storytelling. From the vivid visuals of digital games to the immersive virtual environments, color serves as a powerful tool that influences user perception, emotional engagement, and gameplay mechanics.

In the context of digital games, individuals with color blindness may have difficulty perceiving certain colors or color combinations, which can affect their ability to accurately interpret and interact with the game world. This can be particularly challenging in games that rely heavily on the use of color to convey important information or to differentiate between different game elements.

This article explores the critical importance of color in the digital realm, particularly from the perspective of color-blind individuals with a specific focus on digital game design. It aims to unravel the impact of color on player experience, visual communication, and the creation of memorable and captivating virtual worlds through

a research study. The following section presents an overview of color blindness and its testing methods to serve as a point of reference for the topics to be addressed in the literature research section and to provide essential background information on the subject matter. In the subsequent section, we conducted a comprehensive review and synthesis of existing studies conducted at the intersection of color blindness and game visualization. Lastly, we summarize the key findings and implications derived from these studies in the fourth and final section.

2. Color Blindness: Conceptual and Theoretical Background

2.1 Understanding Color Blindness

Color blindness, also called color vision deficiency, is a condition where people have difficulty seeing colors in the same way as people with normal color vision. This can affect their ability to distinguish between different colors or to see colors at all. Flueck (2006) argues that ''The first scientific paper about color blindness was written by John Dalton in 1793 entitled "Extraordinary facts relating to the vision of color ". Dalton himself was red- green colorblind and as a scientist he took interest in this topic. He claimed that a colored liquid inside the eyeball is the source for a different color perception. This was proved wrong only after his death, when his eyes were examined and no such liquid was found.''(Flueck, 2006).

Color perception in the human eye is built up by three different types of cones. Each type is sensitive to a certain wavelength of light (red, green, and blue) and every perceived color is therefore a mixture of stimuli of those three cone types. The type of affected cones also has a big impact on your color vision deficiency. As there are three different types of color receptors, there are also three different main forms: red (protan), green (deutan), and blue (tritan) disorders. As red and green deficiency result in quite comparable color vision problems, they are often taken together and known as red-green color blindness. Futagbi, G et. al. (2011) categorized the color blindness as following:

- Monochromatism: Either no cones available or just one type of them.
- Dichromatism: Only two different cone types. Third one is missing completely.
- Anomalous trichromatism: All three types but with shifted peaks of sensitivity for one of them, which results in a smaller color spectrum.
- Dichromats and anomalous trichromats exist again in three different types according to the missing cone or in the latter case of malfunctioning.
- Tritanopia/Tritanomaly: Missing/malfunctioning S-cone (blue).
- Deuteranopia/Deuteranomaly: Missing/malfunctioning M-cone (green).
- Protanopia/Protanomaly: Missing/malfunctioning L-cone (red).

Table 1: Different forms of color deficiency (Ismail, 2015)

Type	Denomination	Prevalence %	
		Men	Women
Monochomacy	Achromatopsia	0.00003	
Dichromacy	Protanopia	1.01	0.02
	Deuteranopia	1.27	0.01
	Tritanopia	0.0001	
Anomalous Trichromacy	Protanomaly	1.08	0.03
	Deuteranomaly	4.63	0.36
	Tritanomaly	0.0002	

Color blindness is a common condition, affecting about 1 in 12 men and 1 in 200 women. Most of colorblind people are male, because the most common form called red-green color blindness is encoded on the X-chromosome and therefore sex-linked. As red-green color blindness is inherited from a mother to her son, a father never passes this type of color blindness on to his male children. Moreover, it is typically inherited and is not usually a sign of any underlying medical condition. (Alamoudi, N. B et. al. 2021)

The term red-green color blindness is often used but actually not quite correct. Every type of color vision deficiency affects the whole color spectrum and therefore cannot be reduced to just certain colors. Another

common misconception about colour-blindness is that color blind people are unable to see certain colors or some colors appear grey for them. Colorblind people are actually unable to distinguish certain colors. (Tanuwidjaja, E et. al., 2014)

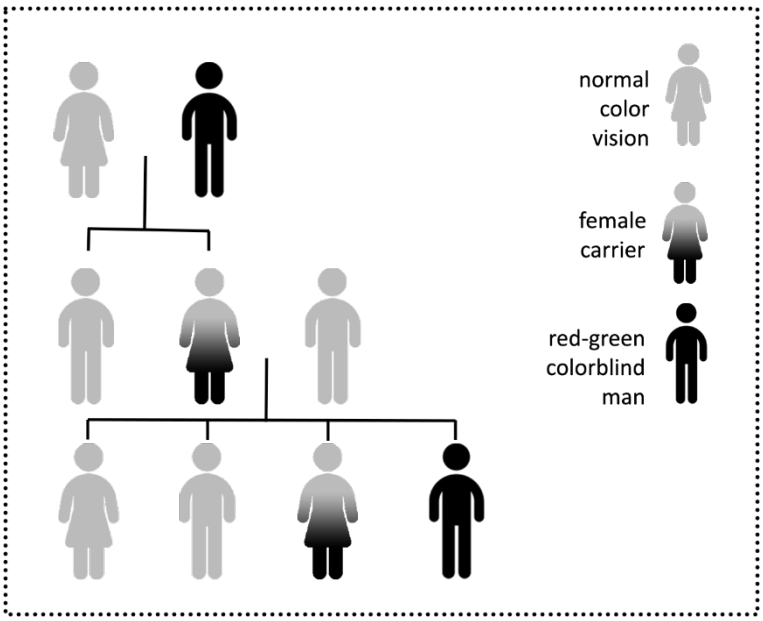

Figure 1: Red-green color blindness inheritance pattern (Flueck, 2006)

2.2 Color Blindness Tests

There are different possibilities to test color vision and it is not possible to accurately count the number of tests available because there are too many tests. Flueck, (2006) mentions that how well-known tests work.

Anomaloscope: It provides the most accurate possibility to test the severity of color blindness and distinguish between dichromats and anomalous trichromats.

Pseudoisochromatic plates: They are the most famous type of color blindness test. Most people know them under the name Ishihara plates test. These plates consist of a series of patterns or figures made up of different colors and shapes. The person being tested is asked to identify the pattern or figure that is hidden within the colors. For people with normal color vision, the hidden pattern or figure is typically easy to see.

Arrangement tests: Also known as ordering tests, are used to test for color blindness. These tests typically involve arranging a set of colored chips or blocks in a particular order based on their color. The person being tested is asked to arrange the chips or blocks in a way that demonstrates their understanding of the colors and the relationships between them.

Lantern tests: They also known as light signal tests, that are used to test for color blindness. These tests typically involve using a special lantern or light signal device that displays different colors and patterns. The person being tested is asked to identify the colors and patterns being displayed. Some commonly used lantern tests include the City University Color Vision Test and the Farnsworth Lantern Test.

There is no single "best" color vision test, as different tests may be more suitable for different situations and individuals. Different color vision tests are designed to test for different types and levels of color blindness, and some may be more effective at detecting certain types of color vision deficiency than others.

3. Previous Studies at the Intersection of Color Blindness and Game Design

This research focuses on exploring the relationship between color blindness and game visualization. During the initial literature search, it was observed that there is a scarcity of studies specifically dedicated to game visualization. Consequently, additional keywords such as "digital visualization" and "user experience" were incorporated in the literature research phase to expand the scope of investigation. Through this iterative process, a final set of keywords was identified to refine the research area, encompassing subjects related to color blindness and game technology, including visual impairments, color vision deficiency, accessibility in games, game interactions, gaming experience, and game art/visualization. A comprehensive literature review

was conducted, involving the exploration of three distinct sources (Scopus, Web of Science, ACM) using various combinations of the identified keywords. As a result, a substantial number of research texts, approximately a hundred, were found to be relevant to the identified subjects. After a preliminary examination of these sources, it was determined that several studies delved into areas outside the scope of our research, such as health and education. Ultimately, fifteen sources were deemed closely aligned with the subject and offered valuable insights for the literature search. Among these, four sources were excluded from the research area due to their detailed focus on engineering and numerical calculations. The remaining sources were thoroughly scrutinized based on the subjects they explored, the methodologies employed, and the outcomes they presented. Given the limited number of studies in the intersection area, the literature search was not confined to a specific type of color blindness. Consequently, a diverse range of articles was considered in the subsequent analysis. The study aims to analyze eleven of these relevant articles in the continuation, contributing to the understanding of color blindness in the context of game design and fostering new perspectives in this evolving field. (table 2)

Table 2: Literature review

N	Article Name	Year	Keywords	Objectives
1	DoDo game, a color vision deficiency screening test for young children	2014	Children game; Color deficiency test; Digital game	Offering an alternative way to detect color blindness in early ages
2	Perspectives on Accessibility in Digital Games	2018	Accessibility; Educational serious games; Serious game design; Customisation; Choices; Alternatives	Arguing the importance of educational games in terms of supporting disabled children and teachers
3	Flying colors: Using color blindness simulations in the development of accessible	2021	Accessibility, Color Blindness, Games, Mobile	Examining the usage of digital simulations to increase accessibility and awareness during the development of mobile games.
4	Chroma: a wearable augmented-reality solution for color blindness	2014	Augmented-reality; Glass; Wearables; Color blindness	Focusing on using AR glasses to improve the vision of colorblind individuals.
5	Exploring the Impact of Colour-Blindness on Computer Game Performance	2018	Accessibility; Colour Blind; Online Games; Performance	Examining the effects of color blindness on casual computer gaming performance and experience
6	Design proto-patterns to improve the interaction in video games of people with color blindness	2019	Video games, Visual Impairment and Color Blindness, Accessibility Barriers, Design Guides and Patterns.	Addressing the challenges faced by individuals with color blindness when playing video games and provide recommendations.
7	The Windows 10's Color Filter Feature as an Aid for Color Blind People in the Use of Websites	2021	Accessibility, Color Blind, Color Vision Deficiency, User Experiences, Windows Color Filter	Discussing whether the Windows 10 color blindness filter is efficient in terms of user experience.
8	See a Different World: Interactive Storytelling for Children to Raise Awareness of Color Blindness	2015	Color blindness--Interactive multimedia Design; Visual communication; Computer games Design	Providing an educational tool that is both engaging and inclusive for all children.
9	The Whose View of Hue?: Disability adaptability for color blindness in the digital game Hue	2018	Game Design, Accessibility, Universal Design, Color Blindness, Hue.	Discussing Hoffman's design process and proposing a framework for accessible game design
10	The composition of visual texture design on surface for color vision deficiency (CVD)	2019	Color vision,Color Vision Deficiency (CVD),Texture composition,Psychophysics, Color threshold	Searching for how different colors, sizes, and distances of textures could help people with color vision deficiency
11	Prototyping "Color in Life" EduGame for Dichromatic Color Blind Awareness	2021	Color blind, Educational game,Gaming experience mobile game	Increasing players' knowledge about color blindness with a game specifically designed for dichromatic color blindness.

Old color blindness tests may need alternatives due to potential limitations in accuracy, accessibility, cultural applicability, specificity, and sensitivity. Embracing alternative tests can leverage advancements in technology, address these limitations, and offer a more effective and user-friendly approach to identifying color vision deficiencies. For these reasons, some studies propose alternatives to the traditional testing methods mentioned in the previous sections. One prominent study (1) conducted by Linh-Chi et. al. (2016) offers a game that incorporates engaging elements, making it suitable for early-age screening. The DoDo game consists of four sub-games targeting different types of color deficiencies, including Yellow-Blue and Red-Green color blindness, total color blindness, and distinguishing between deuteranopia and protanopia. By identifying color vision deficiencies at a young age, potential challenges in learning and academic performance related to color-dependent tasks can be addressed promptly. The interactive and game-like nature of the DoDo game makes it a more engaging and less intimidating option for young children compared to traditional color screening methods that may rely heavily on cognitive or verbal abilities. The DoDo game's effectiveness in identifying Red-Green color deficiencies, comparable to established screening tests, implies its potential as a reliable alternative.

However, it is important to note that the study was conducted with a relatively small sample size of 28 children in Singapore. Further research with a more extensive and diverse participant pool would be beneficial to validate the game's effectiveness in various populations. alternative.

Some researchers support that AR technology is very useful in game development and in increasing the game experience such as Pinheiro et al. (2021). Study(**3**) highlights the significance of integrating chromatic accessibility into the design process by using simulations at various stages of game development. The research aims to address three key questions: first, whether augmented reality simulations are beneficial for considering chromatic accessibility during the design phase; second, if there are specific accessibility problems that only a particular simulation type can detect; and third, whether using augmented reality simulations provides advantages over screen simulations. Study show that early identification of accessibility issues ensures a more inclusive gaming experience for color-blind individuals and enhances the overall user experience for all players. The experiment involved utilizing simulations on both desktop and augmented reality platforms during the development of an actual mobile game, comparing the use of augmented reality simulations with filters applied to the screen. This comparison between augmented reality and screen simulations offers valuable insights, empowering developers with options that align with their specific needs and resources. Moreover, the study highlights the necessity of using a mix of simulation methods to fully evaluate and address accessibility issues effectively. An additional study(**4**) executed by Tanuwidjaja, et. al. (2014) reinforces this matter by exploring the use of scrutiny glasses to enhance the user experience. They focused on using AR glasses to improve the vision of colorblind individuals. To address this issue, a wearable augmented-reality system known as Chroma was developed based on Google Glass, allowing users to view a filtered image of their surroundings in real-time. Chroma's objective is to assist colorblind users in distinguishing colors they typically struggle to see, thereby providing them with access to different color dimensions and enhancing their everyday activities. To provide that it adapts the scene-view based on the type of color blindness and includes algorithms for color saliency. The research group conducted interviews with 23 people with color blindness and implemented four modes to assist them in distinguishing colors they typically cannot see. While AR technologies still has limitations, initial tests demonstrated promising results, indicating that colorblind individuals using the wearable AR device could improve their color recognition abilities. The implementation of AR glasses holds significant potential to enhance the daily lives of colorblind users by facilitating color perception and aiding them in tasks where color identification is crucial.

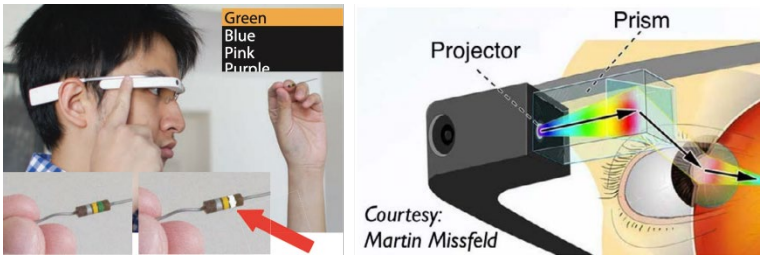

Figure 2: Colorblind person wearing Chroma glasses (Tanuwidjaja, et. al, 2014)

Hauge et al.'s (2018) article(**2**), brings to light the crucial issue of accessibility in educational games, especially for students and teachers with impairments. Researchers explore strategies to enhance the accessibility of educational games, with a particular focus on addressing visual impairments in games used for STEM education. It underscores the significance of making educational games more inclusive to support disabled individuals and foster equitable learning experiences. The proposed solutions, including enhancing visual accessibility and incorporating text-to-speech input, address significant barriers faced by students and teachers with impairments. The introduction of the Accessabar platform as a potential solution is an intriguing aspect of the study. Although the specific details of the platform are not provided in the review, the concept of a comprehensive tool to address multiple accessibility needs in digital games is highly promising. The Accessabar platform seems to offer a versatile and unified solution to support various impairments.

Napoli and Chiasson (2018) conducted a comprehensive study(**5**) which diligently examined the effects of color blindness on casual computer gaming performance and overall user experience. Through online puzzle game experiments conducted in both regular and simulated color-blind environments, the researchers found that while objective measures did not demonstrate a significant decline in gaming performance due to color blindness, the participants' subjective perception of the game's difficulty was influenced. This discrepancy emphasizes the need for further exploration of the influence of color vision deficiency on gaming experiences.

In a separate study(**7**), Paiva et al. (2021) proposed meticulously investigating the effectiveness of the Windows 10 color blindness filter in enhancing user experience on websites. Their findings demonstrated notable improvement across various scenarios, with varying degrees of effectiveness based on the type of color blindness. The study's results demonstrated improvement in user experience for most scenarios when using the color filter. However, the degree of improvement varied depending on the type of color blindness. The protan type color blind group saw the most significant improvement, particularly in situations where websites required user actions. On the other hand, the deutan type color blind group experienced the least improvement, but interestingly, they rated the overall experience the highest. These studies collectively emphasize the critical importance of considering color vision deficiency in design and accessibility guidelines to ensure inclusive and enhanced user experiences in gaming and website usage.

Awareness of color blindness in early ages is crucial because it allows for timely identification, enabling children with color vision deficiencies to receive appropriate support and accommodations in their educational and daily activities. Both the articles by Ivan et al. (2021) and Dan (2015) center around the objective of raising awareness and promoting understanding of color blindness. Ivan et al.'s study(**11**) focuses on the development of an educational video game called "Color in Life," specifically designed for individuals with dichromatic color vision deficiency. The game utilizes tailored graphics and gameplay to provide an interactive learning experience about color blindness. The positive findings, indicating an increase in players' knowledge and awareness of dichromatic color vision deficiency after playing the game, validate the effectiveness of the tailored game design. Moreover, the game's accessibility and appeal to both individuals with and without color vision deficiency highlight its potential to be an inclusive and informative educational tool for a broader audience. On the other hand, Dan's article(**8**) delves into the realm of interactive storytelling, presenting an alternative approach to educating children about color blindness. Study addresses the limited availability of interactive applications specifically designed for children with disabilities, with a particular focus on children with color blindness. It aims to fill this gap by developing an interactive visual storytelling application called "See a Different World" that serves as an engaging and inclusive educational tool for elementary school-aged children. The "See a Different World" interactive application incorporates unique characters, colorful elements, and engaging reading and playing activities to raise awareness among young audiences. The application incorporates reading and playing activities to facilitate learning about color blindness and includes a short color-blind test to help children understand their own color perception. both articles recognize the potential of digital technology, particularly digital game art and interactive storytelling, as effective mediums to convey information and promote awareness about color blindness.

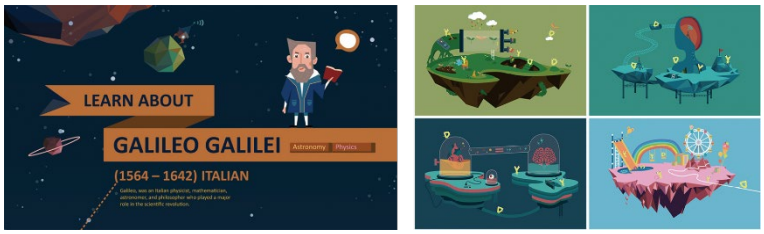

Figure 3: Design ideation (Dan, 2015)

In the study(**6**) conducted by Josefa and Nuria (2019), the researchers provided a thorough analysis of the challenges faced by individuals with color blindness in the context of video games, which aligns with the study(**9**) by Plothe (2018). Both studies focus on addressing color vision deficiency in game art to enhance the interaction and gameplay experience for individuals with color blindness. Josefa and Nuria proposed 12 design prototype patterns that offer practical and effective recommendations, such as setting alternative colors for better perception by color blind individuals, associating labels and shapes with characters and interactive elements, and enabling customizable visual effects. Similarly, Plothe's research on "Hue" showcases how accessibility for colorblind players was carefully considered in the design process, leading to the incorporation of built-in and customizable modes using patterns instead of colors to ensure inclusivity in gaming. Article delves into the journey of transforming the digital game Hue from exclusion to inclusion for colorblind players. The interview-based case study with the game's creator, sheds light on the design process that led to the implementation of built-in and customizable modes, making the game more accessible for colorblind individuals. Together, these studies underscore the crucial importance of adopting universal design principles and inclusive approaches to create video games that cater to the needs of individuals with color blindness.

Tseng and Cheng's (2019) study(**10)** provides essential insights into the realm of visual accessibility, addressing the challenges faced by individuals with CVD. The research delves into crucial design elements like colors, sizes, and distances of textures, aiming to enhance color perception while preserving visual appeal for normal vision individuals. The incorporation of specific parameters, such as RGB color 234, 0, 21, element size 2.50, and distance 2.5', underscores the rigorous and thoughtful approach taken in identifying effective solutions. The study's recognition of the potential influence of material and environmental factors on the proposed design elements reflects the researchers' commitment to real-world applicability. This research not only advances accessible design practices but also fosters a more inclusive digital landscape, promoting meaningful engagement with visual content for all users.

4. Discussion and Conclusion

In the previous section, it has been determined through research that there have been a significant number of studies conducted on the topic of color blindness and its impact on game design. A total of 11 selected sources have been analysed in terms of their methodologies, content and findings. Based on the reviews, it has been observed that three methodologies are predominantly used in research: human experiments, pre-tests, and interviews. Researchers used pretests to establish reliability and validity, provide baseline measurements, identify outliers, monitor participants' progress, and address ethical considerations before the main study. Additionally, it is worth noting that many studies in this field have utilized a combination of these methodologies to support their research process. For instance, the majority of the studies that conducted measurements on the experimental group first utilized traditional color blindness tests to compare the results and draw inferences by contrasting this data with their own experimental setups.

Thorough analysis and interpretation of the research outcomes, the findings of these studies were grouped into two categories: numerical data and verbal comments. Studies 2, 6, 7, and 9 utilized verbal assessments rather than numeric data in presenting their findings. In contrast, the 10th study employed a numerical data-driven approach to represent its research outcomes, reflecting a different methodological approach. While only a minority of the studies focused solely on addressing the proposed theoretical framework, a significant proportion aimed to serve as references for future research by generating novel discussions based on hypotheses supported by numerical data. This observation indicates a growing trend within the research domain, emphasizing the importance of empirical evidence and quantitative analysis in advancing the understanding of the subject matter.

Table 3: Classification of articles

<table>
<tr><th>Content</th><th>Methodolgy</th><th>Findings</th></tr>
<tr><td>Examining technologies:
3, 4, 7,</td><td rowspan="2">Human experiment:
11, 10, 8, 7, 5, 4, 3, 1</td><td rowspan="2">Numerical analyses:
1, 3, 4, 5, 8, 10, 11</td></tr>
<tr><td>Defining guidelines to provide better game experience:
2, 6, 9, 10,</td></tr>
<tr><td rowspan="2">Offering alternative methods for detecting color blindness:
1, 8, 11</td><td rowspan="2">Applying a pretest/form:
7, 8, 11, 5, 1, 4</td><td rowspan="3">Verbal analyses:
1, 2, 3, 4, 5, 6, 7, 8, 9, 11</td></tr>
<tr><td></td></tr>
<tr><td>Examining impacts of color blindness on user performance:
5, 7,8, 11</td><td>Interviews:
9</td></tr>
</table>

The studies in the intersection between color blindness and game design mostly focused on single subjects, except for one that explored multiple subjects simultaneously. This highlights the diversity in methodologies and approaches used within the academic landscape to address research questions and explore various aspects of the chosen subject matter. The researches were organized into various subject headings for further analysis of their content, covering topics such as defining guidelines for better game experience for color blind individuals, examining the impacts of color blindness on user performance, offering alternative methods for detecting color blindness, and exploring technologies to improve the visual experience for color blind individuals. One of the four main research areas in this study is the improvement of color-blind individuals' gaming experience with the

support of advancing technology. As mentioned earlier, both Study 3 and Study 4 have explained through tests that technology contributes positively to color-blind players' gaming experience. Another area that many studies have focused on is the modernization of traditional testing methods through digital games, making them more appealing and encouraging early diagnosis for individuals of all age groups. Studies 1, 8, and 11 all highlight the importance of digital games in detecting color blindness, especially at an early age. Unlike other research areas that primarily discuss the accessibility aspect of games for color-blind individuals, this research topic introduces a fresh perspective by proposing that games can be utilized as a method for detecting color blindness, offering a novel approach to the subject. Moreover, some studies measure color-blind individuals' digital game experiences and performance, while others offer recommendations to mitigate the identified negative implications. These reference-worthy recommendations can be highly beneficial for game developers.

One particularly noteworthy finding comes from Study 5, where the evaluation indicates that color blindness does not have a direct impact on performance, but participants' emotional perceptions are affected. However, it was revealed that no study was included which questioned whether color blindness causes differences in emotional and physical responses among individuals with different visual abilities (color blind individuals and individuals with normal visual ability). Based on the lack of research on the subject, carrying out a future study that will involve a group of people with different ages and vision abilities completing emotional analysis tests after interacting with games in both a normal and simulated color-blind environment can be beneficial to fill the gap in the academic field. Physical(such as heart rhythm, mimics) and emotional responses(such as happiness, sadness) will be measured to determine if color blindness causes differences about reactions in players' experiences.

To sum up, in recent years, there has been a growing awareness of the importance of considering accessibility for players with color blindness in the design of video games. Researchers have explored various techniques for improving the visibility of game elements for colorblind players, including the use of patterns and texture, as well as alternative color schemes and customizable settings. These efforts have helped to make games more inclusive and accessible to a wider range of players. However, there is still much work to be done in this area, and further research is needed to fully understand the impact of color blindness on gameplay experience and to develop effective design strategies for supporting players with this disability. Overall, it is clear that game designers and researchers must continue to prioritize the inclusion of players with color blindness in the design and development process in order to create truly accessible and enjoyable gaming experiences for all.

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Combine DGBL With AI System: A Technical Guidance to Reduce Teacher' s Burden in Digital Game-Based Learning

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Abstract: Game-based learning has been regarded as a increasing popular method in current teaching process, however, it really burdens teacher as it requires teachers to invest abundant energy and time to design. Aims at reducing teaching burden, this research has proposed a guidance system design based on large language model (LLM) and blockchain technology. In this design, system framework has been divided into 3 layers: user layer, application layer and technical layer. Initially, teachers input their instructional plans, while students signing up their learner profiles. This information is securely recorded on the blockchain for data integrity. The results stemming from data prediction and feature engineering are then incorporated into the LLM , facilitating the visualization of strategies tailored to address specific learning challenges. As the process advances, the information undergoes automated scrutiny to evaluate the learning conditions, ultimately selecting an appropriate DGBL cases with a proven track record in similar scenarios. This aids teachers in crafting personalized learning blueprints, informed by the insights gleaned from the feature engineering analysis and its impact on students' learning experiences. The concluding phase involves tracking and assessment, wherein an automated evaluation of student performance is conducted based on study data and LLM-generated questionnaires. Teachers subsequently review the results and recommendations to enhance the quality of their instructional methodologies, and the learner portrait will also be renewed according to received data. This guidance system still has some disadvantages, such as lacking sequential consistency in the responses generated by the model. In summary, a future direction for this research is to develop specific LLM systems for specific school segments and instructional needs to help teachers implement DGBL.

Keywords: Digital game-based learning, Large language model, Blockchain

1. Introduction and Background

Implementing game-based learning still presents certain challenges, especially in terms of the demands it places on teachers' capabilities. During the implementation of game-based learning, teachers need to spend a significant amount of time calculating the difficulty level and time investment of games and assessing whether students' knowledge levels meet teaching requirements after the game concludes (Venera-Mihaela & Boghian, 2014). However, not every teacher has the energy to invest substantial time in evaluating the outcomes of game-based learning, which really burdens teachers when designing game-based learning. Teachers have found that they have to invest abundant time in design instructional games during teaching process, and hope to reduce this kind of burden while they think game-based learning can be effective.

Therefore, it is essential to discuss how to construct a game-based learning system to support teachers design activities during teaching process. This article will describe a learning analysis system build on blockchain and large language model, which aims at assisting teachers to establish game-based learning.

2. Literature Review

2.1 Game-based Learning (GBL)

Game-based learning refers to a pedagogical approach that utilizes game environments or elements to conduct instructional activities, impart teaching knowledge, and achieve educational objectives (P.-Y. Chen et al., 2022).

Embracing the use of game-based learning strategies often demands an increased level of preparation and allocation of resources. Teachers find themselves have to invest abundant time into the exploration and selection of appropriate educational games that align with their instructional goals (De Gloria et al., 2014; DeCoito & Estaiteyeh, 2022). Furthermore, they must acquire proficiency in the art of seamlessly integrating these games into their pedagogical practices (Su et al., 2019). There is a natural inclination among some teachers to resist the adoption of game-based learning due to concerns about the extra effort required. Moreover, the learning curve associated with incorporating game-based elements into teaching should not be underestimated. Teachers must familiarize themselves with the mechanics, dynamics, and aesthetics of various educational games to ensure their effective implementation (Belda-Medina & Calvo-Ferrer, 2022). In summary, the reluctance of teachers to embrace game-based learning can be attributed, in part, to the heightened demand for preparation and resources it entails. This research is responsible for this question.

2.2 Large Language Model

Large language models (LLM) are a type of natural language processing (NLP) model based on deep learning neural networks, primarily designed for understanding and generating natural language text (M. Chen et al., 2021). Compared to regular language models or analytical approaches, LLM allow models to learn features at various abstraction levels when processing text, from characters and vocabulary to higher-level grammar and semantics (Austin et al., 2021). Consequently, large language models are widely used for a variety of natural language processing tasks, including sentiment analysis, named entity recognition, summarization generation, machine translation, text classification, search engine enhancements, intelligent question-answering systems (Guu et al., 2020), and more.

In the field of education, LLMs are also considered to have numerous potential applications. LLM can facilitate personalized education by analyzing students' learning needs, interests, and abilities. Educators can use these models to generate customized learning plans, course materials, and exercises to meet the needs of each student (Abd-alrazaq et al., 2023; Owan et al., 2023). For instance, LLMs can provide tailored resources for each student, thereby enhancing the learning outcomes (Murgia et al., 2023). Secondly, LLMs can be integrated into educational tools and platforms to offer immediate learning support (Abd-alrazaq et al., 2023). Specifically, students can pose questions to LLM-based tools, and the model will provide answers based on the complexity of the question and the student's knowledge level (Kiesler et al., 2023). Consequently, employing large models aids in helping learners access learning materials and somewhat alleviates the burden on teachers. Additionally, LLMs can generate educational resources such as lesson plans, lecture notes, exercises, and quizzes (Gilson et al., 2023; Shen et al., 2023), as well as evaluate learners' performance throughout the learning process, thereby providing learners with real-time feedback on their learning performance (Ajevski et al., 2023). As previously mentioned, the design of game-based learning necessitates teachers to seek relevant teaching resources and design game-based learning instructional plans based on learners' situations. LLMs can assist users in finding relevant resources and providing answers based on user feedback, making them a potential tool for instructional support.

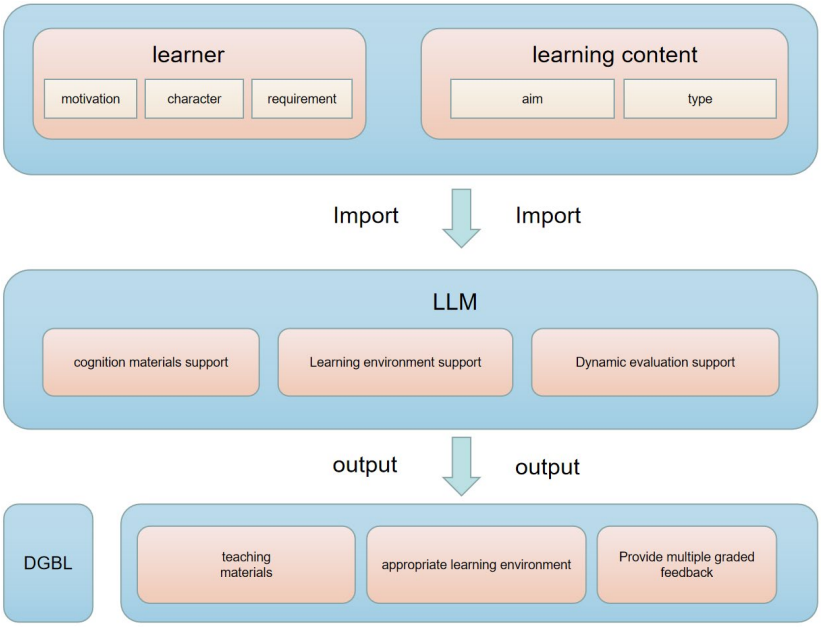

Figure 1: The function of LLM to DGBL

2.3 Blockchain

Blockchain is a cryptography technology that generates, stores, and analyses data according to distributed consensus algorithms (Alsharari, 2021; Gadekallu et al., 2022). Its fundamental concept revolves around decentralization, achieved through distributed ledgers and robust cryptographic techniques, enabling secure, transparent, traceable, and tamper-proof data storage and exchange (Guergov & Radwan, 2021). Notably, blockchain technology has found utility in the field of education. Firstly, its decentralized and secure features position it as a safe storage and verification method for student academic records and achievements. Information can be stored in a distributed manner on the blockchain, thus mitigating the risk of diploma fraud

and academic record manipulation, and facilitating easier verification by prospective employers and educational institutions (Alam, 2022; Alammary et al., 2019); students have the option to selectively share their academic records and achievements without disclosing all information, thereby safeguarding their privacy and allowing them to have better ownership of their educational data (Saleh et al., 2020; Steiu, 2020). Consequently, blockchain is considered a potential tool for safeguarding data produced during teaching process.

3. Technical Structure and Working Process

3.1 Structure

The following figure 2 has shown the working process of LLM-blockchain guidance system.It includes 3 layers to support the guidance for teachers to design game-based learning: user layer, application layer, and technical layer.

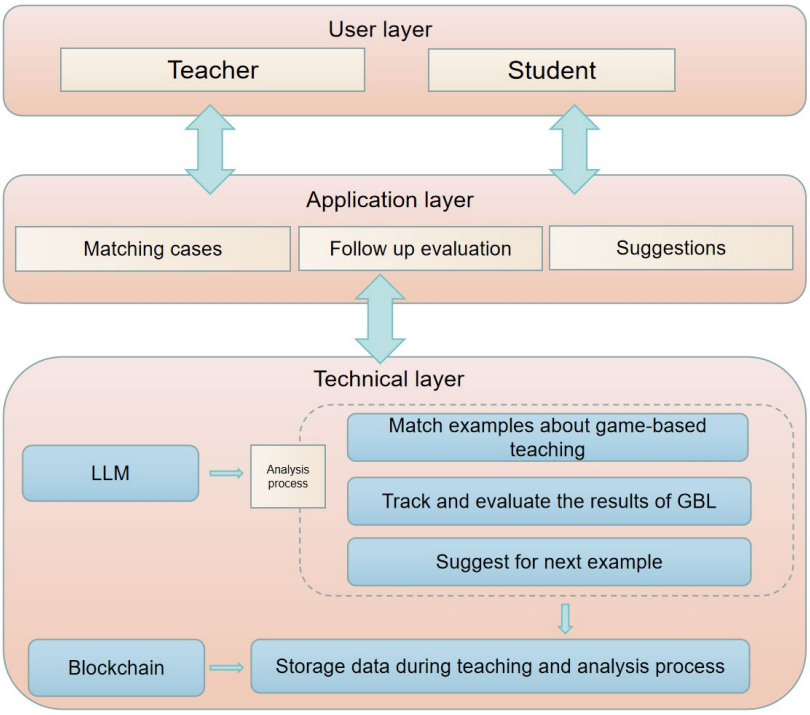

Figure 2. System layers

User Layer

User layer has mentioned 2 main using groups using this system, teachers and students. This layer is responsible for collecting data from users, specifically, which can receive data that being scanned automatically from digital games and input manually from users. In addition, it also responsible for transform data from other layers to user's interface. At the same time, teachers and students can also transform and observe data during teaching process, in order to update and grasp the tendency of data fluctuation.

Application Layer

The application layer, then, is where the data analysis that serves as the basis of suggestions to teachers regarding the implementation of DGBL takes place. It will responsible for connect technical layer with user layer, which has provided functions based on technical support. Firstly, it will help teachers to match cases, in order to provide practical references for teachers to design DGBL process. Meanwhile, it is also helpful to follow up evaluation during learning process when users allow it to track data produced in DGBL and input manually by users, which means it can provide assistance for evaluating learner's performance and make things clearly to satisfy teacher's requirements about learner analysis. Consequently, based on the matched cases and learners analysis results, it can provide suggestions for teachers regarding specific requirements set by users.

Technical Layer

Two technologies in technical layer, LLM and blcokchain, are responsible for supporting system framework in technical dimension.

LLM (LLM) deals with data analysis process in system. Based on the input of diverse datasets, LLM utilizes the transformer architecture, which consists of encoder and decoder components. Encoder in LLM can take the input text and converts it into a series of high-dimensional representations, which captures the contextual information of the text that are generated by stacking multiple layers of self-attention mechanisms and feed-forward neural networks. This enables LLM to capture long-range dependencies and contextual information effectively, therefore analysis learner's performance and teacher's instruction. In addition, using multiple layers in the encoder-decoder framework helps in learning complex patterns and generating high-quality responses, especially the self-attention mechanism enables the model to capture long-range dependencies and contextual information effectively, allowing it to generate coherent and contextually appropriate responses (Naidu & Sevnarayan, 2023). This enables LLM can generate smooth suggestions based on its complex encoder structure, as a result, LLM can be an effective technology to accomplish analyzed process in guidance system.

Blockchain deals with the storage of data. During the using process, data will be divided into private chain, public chain and alliance chain, aims at ensuring all types of information can be storage well instead of leaking it.

3.2 Working Process

This guidance system design for providing guidance for DGBL design and implement. Initially, teachers input their instructional plans, while students signing up their learner profiles. This information is securely recorded on the blockchain for data integrity. The results stemming from data prediction and feature engineering are then incorporated into the LLM , facilitating the visualization of strategies tailored to address specific learning challenges. As the process advances, the information undergoes automated scrutiny to evaluate the learning conditions, ultimately selecting an appropriate DGBL cases with a proven track record in similar scenarios. This aids teachers in crafting personalized learning blueprints, informed by the insights gleaned from the feature engineering analysis and its impact on students' learning experiences. The concluding phase involves tracking and assessment, wherein an automated evaluation of student performance is conducted based on study data and LLM-generated questionnaires. Teachers subsequently review the results and recommendations to enhance the quality of their instructional methodologies, and the learner portrait will also be renewed according to received data.

4. Discussion and Conclusion

This research has proposed a system to design DGBL teaching process, which aims at reducing teacher's burden during design process. Currently, this system has covered the whole implement process of DGBL from teaching plan before class and learner portrait after class. Therefore, it seems like a practical system that can be used in realistic teaching circumstance. However, this system is based on the LLM system, which means it will caused variety of problems that brought by LLM itself.

One of the limitations is the lack of explicit modelling of sequential dependencies, as each markerin LLM is processed independently in parallel, which can sometimes lead to a lack of sequential consistency in the responses generated by the model (Brown et al., 2020). Another challenge is the potential for over-reliance on surface-level patterns in the training data, leading to the generation of responses that appear reasonable but are incorrect or meaningless. This has been referred to as the "cueing problem" in language modelling (Liu et al., 2023). For example, some researchers have found that the LLM produces completely irrelevant research ideas and literature when generating literature reviews (Leiter et al., 2023; Lin, 2023). Therefore, based on the current workings of the system, the accuracy of the answers generated by the system may be challenged, and the accuracy and sequence consistency of LLM answers generated under different conditions may be a factor to consider.

Secondly, as LLM answers are based on existing databases and pre-training rather than independent thinking (and indeed, LLMs are unlikely to be able to think independently), the quality of their answers is heavily dependent on the quality of the training materials which will still require extensive pre-training by the developer or instructor. Therefore, it remains to be explored whether this can actually reduce the burden on teachers. In addition, the output of the LLM is based on statistical rules and patterns learned during the pre-training process, which may lead to the generation of answers that lack practical judgement and logical reasoning. For example, when a researcher uses LLM to analyse data from the literature, Type I errors may occur, which may affect the

veracity of the research data analysis (Dalalah & Dalalah, 2023). Therefore, if one intends to use LLM in a specific educational field, one needs to develop training LLM according to the characteristics of this field so that this system can be more relevant for teaching in a particular field.

In summary, a future direction for this research is to develop specific LLM systems for specific school segments and instructional needs to help teachers implement DGBL.

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Work in Progress Papers

Science4Exitschool: Escape Games for Chemistry Classes

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Abstract: Chemistry can often be very abstract. For this reason, different learning environments and methods are increasingly being developed to make it more accessible to learners at school or university. One such method is the use of educational escape games (Avargil, Shwartz and Zemel, 2021). This term refers to live-action, team-based games. In these escape games, clues must be followed, puzzles and tasks must be solved within a certain time frame in order to reach a certain goal (Tercanli, Martina and Ferreira Dias, 2021). This concept offers new opportunities for the educational sector. Learning pedagogy categorises this as game-based learning. The game serves as a medium for learning and achieving specific learning goals (Hu *et al.*, 2022). Entertainment is not the main focus, but should be used in a targeted way to convey knowledge or elicit certain behaviours (Sailer, 2016). Through experimental escape games with digital enrichment, previously acquired knowledge can also be applied and consolidated. As not only the popularity of the subjects of chemistry and physics has declined, but also scientific competences (Dohrmann, 2019), it is particularly relevant for the STEM field to introduce students to these topics in a playful way (Veldkamp *et al.*, 2020) and thus increase their interest in dealing with scientific topics. Escape games have already been shown to promote teamwork, problem-solving skills and creativity (Hacke, Przybylla and Schwill, 2019). These skills are part of the 21st century skills. In the context of the Science4Exit$_{school}$ project, this concept will be applied to the teaching of chemistry in schools. In addition to the technical background, the paper will also describe how this innovation can be implemented as an example.

Keywords: Escape games, Gamification, Chemistry classes, learning

1. Theoretical Context

Gamification refers to the application of game content and mechanics to educational or non-gaming contexts. Through the use of different processes and activities, a connection can be made between learning and game elements (Kim *et al.*, 2018). Gamification has been found to have positive effects on motivation, engagement, well-being, participation, interaction and collaboration among learners (Sailer, 2016). As society is constantly changing, the way we learn is also evolving. Due to its attractive and motivating nature, playful content is increasingly being implemented in learning contexts, especially in schools. Play is an intrinsically motivated activity for children and young people that helps them to solve problems, interact with others and their environment, and acquire realistic skills (Oerter, 2007).

With the rapid development of digital and social media, there is a great opportunity to expand gamification into the field of knowledge transfer (Jacob and Teuteberg, 2017). When a game is used with a specific learning objective in mind, it is referred to as game-based learning (Tercanli, Martina and Ferreira Dias, 2021). One method of game-based learning is educational escape rooms, which are becoming increasingly popular in providing learners with a new learning and assessment environment (Fotaris and Mastoras, 2022). Educational escape rooms are live-action games in which players, usually in teams, solve puzzles and tasks and follow clues, with a focus on teaching learning content or applying previously learned knowledge. The primary goal is to escape from a room, and the games can be embedded in different themes that lead to different missions (Veldkamp *et al.*, 2020).

However, due to safety concerns in chemistry, it is not possible to lock students in a laboratory. Therefore, there is a variation of this method, known as escape games, which can exist virtually or in the imagination. In these games, various locked objects are integrated in addition to puzzles and tasks (Dietrich, 2018). Escape games can be played flexibly in the classroom, online, with a box or as a board game (Menon, Romero and Viéville, 2019). In the educational context, puzzles and problems can be based on a technical challenge and thus on an operationalisable learning objective (Strippel, Philipp Schröder and Sommer, 2022). In the field of chemistry, these are chemical professional competences such as experimentation, scientific literacy, etc.

1.1 Escape Games

An escape game can be structured in a number of ways, with six key elements at its core. The game needs a *narrative*, which involves giving the game a compelling story. To coordinate the different stages of the game, you need to consider the *game-flow*, which gives the game its structure. Two other elements are needed during gameplay: *puzzles* and *equipment*. Puzzles represent the various tasks and puzzles that require both

physical and cognitive skills and can vary in difficulty. The design of the game can be implemented using equipment, which can be digital or physical. The category of educational escape games includes two other essential elements: *learning* and *debriefing*. Learning involves the delivery of curricular and extracurricular content and the development of specific competencies. Debriefing refers to the post-game process that completes the learning phase. This can ensure sustainable knowledge acquisition (Remmele *et al.*, 2020).

2. The Project Science4Exit$_{\text{SCHOOL}}$

Under the title "Science4Exit School", a PhD project is developing, testing and evaluating, using quantitative questionnaires, various escape games for chemistry lessons from grade 7 onwards. The escape games are intended to provide a motivating framework for students to engage with the subject matter, deepen their understanding and achieve a transfer of learned knowledge through a game-based context. In addition to traditional puzzles, the escape games include chemical experiments and digital enrichments (e.g. subject-specific content). Students are guided through the game via a digital learning environment implemented by embedding the escape games in an application such as Actionbound, genially, H5P, etc. These learning environments also include digital enrichments, such as explanatory videos, which provide background information, additions or assistance to the chemistry content in a didactically reduced way to support the students.

An escape game might involve a fictional criminal case. Various chemical experiments are embedded in a storyline to help catch a criminal. The different investigation methods include determining the colour composition of different pens, visualising secret messages, and visualising and matching fingerprints. The colour composition can be determined by the students using paper chromatography to find out whether a letter was written with a particular pen or not. For this investigation, you need a piece of filter paper with a hole cut in the middle with scissors. Two different colour samples are then applied to each side of the hole. Another piece of filter paper, rolled into a small wick, is pushed through the hole in the filter paper. The filter paper is then placed on a petri dish of water with the wick in the water. The water diffuses along the wick, carrying with it the water-soluble parts of the dye mixture on the filter paper. Due to the different solubility in water and the different strength of adsorption of the individual colour components on the filter paper, the mixture is then separated into individual colour components. (Figure 1). As most colours are mixtures, the resulting images will vary depending on the manufacturer and composition. The results of the investigation serve as new clues in the game, bringing the players step by step closer to catching the culprit.

Figure 1: Result of a paper chromatography

In addition to experiments, classic puzzles, which can also be linked to chemistry content, are essential. For example, the periodic table and its structure lend themselves to integrated puzzles (Figure 2). The atomic numbers of each element can be used to generate numerical codes needed to break a combination encryption method (such as the Caesar cipher), which the students have to decipher.

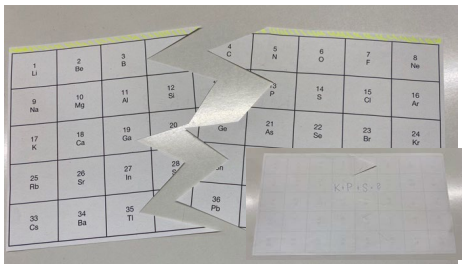

Figure 2: Periodic table puzzle (front and back side)

The developed escape games will be tested in schools, optimised and finally made available to schools as innovative teaching and learning materials. The escape games are designed in such a way that teachers can run them independently in their classes without the need for expensive equipment. This promotes equal opportunities regardless of the facilities or equipment of different schools.

The project is empirically supported and focuses on teacher and student motivation, feasibility and sustainable learning.

3. Prospects

This project will develop, test and evaluate additional escape games for use in schools on relevant topics in chemistry education. In cooperation with teachers, the method and its applications will be adapted and prepared according to the needs, so that the developed materials can be used in a variety of ways in the school context.

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Tierschutz erLeben. Devising a "Comic Automaton" to Innovate Learning

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Abstract: The ongoing German R&D project Tierschutz erLeben aims to improve the animal welfare learning experience, primarily for agricultural students. The knowledge domain is shaped by many interrelated facts, often about informed decision-making under specific circumstances and the possible consequences. Unsatisfactory frontal teaching prevails in the current praxis. In contrast, the abstraction level and the complexity are less demanding. An interactive simulation close to reality is not necessarily a solution as it can be inefficient and incomplete, failing to cover all necessary facts. We are working on an innovative gamified approach based on the concept of interactive comics, which shall be more efficient than realistic simulations potentially encompassing all necessary facts. In our sense, an interactive comic is a form of a simulation with a comic's feel and look. We call it a Comic Automaton. As with every comic, our system presents only relevant story events, thus promoting efficiency. Textual descriptions, diagrams, and other means that help attain completeness are easily incorporated. A Comic Automaton is highly interactive. The immediate goal of the learner is to interactively and iteratively create a story about management in animal husbandry, where every decision is correct and substantiated. Accomplishing a complete, correct comic is an indicator of learning success and shall be an experience of fun and satisfaction. Decisions of the learner, including mistakes and lacuna of knowledge, will trigger automatic continuation of the comic. For example, a comic frame where the user decides not to feed enough milk to a calf will trigger an automatic new frame where the calf becomes weak and possibly even dies. Especially in the field of animal husbandry, virtual exercises that might also have a bad outcome for the animals are very important. Without real animals coming to harm, important lessons can be learned from these mistakes. The details of the Comic Automaton are ongoing work. Two user-centred workshops were held so far to unfold further and test the ideas.

Keywords: Simulation, Decision-making, Animal husbandry, Animal welfare, Storytelling

1. Introduction

The common practice of livestock farming is discussed controversially in society, and various approaches aim to improve animal welfare in livestock farming (Spiller et al., 2015; Boehm, 2010).

However, scientists from the agricultural and animal sciences also complain about a gap in the transfer of knowledge from research to practice (Hoischen-Taubner, 2021) and that the knowledge is not fully implemented on farms (PaeRi, 2020).

Creating attractive learning content that transfers new knowledge to trainees and students is crucial for effective application on farms. The innovative media didactics approach is a key focus of this project. The interdisciplinary team comprises game and graphic designers, media computing, veterinary and agricultural scientists and students.

How can realistic situations on farms be taught? And how can this be effectively processed in a digital form? Finding answers to these questions is a central goal of the R&D Project Tierschutz erLeben.

During the first year of the project, ideation and evaluation were on focus. Our initial approach developing a 3D game-like learning environment that would be visually and with regard to the behaviour of animals and things in it "realistic" was dropped early because "realistic" treatment of cows and sheep in a simulation is very time-consuming, and thus not an efficient approach to learn specific things. Instead, we decided to focus on a modus of representation and storytelling that would expose the user only to story and learning path-relevant farm events, skipping everything else.

2. Interactive Comics

We are currently developing and testing the Comic Automaton concept to meet the following requirements... (a) it fosters learning by trying and doing, (b) it integrates learning assessment and a learning strategy, (c) it contains game elements for additional structure and motivation, (d) it is visually attractive and easy to

understand, (e) the experience is overall inviting and encouraging, rather than dry and “traditional”, (f) it represents and simulates correctly farm situations and animal behaviour, and shows consequences of correct and wrong decisions, (g) it is not only a platform for trying and testing, but also for learning for examinations, integrating text and visual explanations, rendering a textbook superfluous, in principle, (h) it allows for the easy integration of storytelling, for identification, structure, and other engagement.

In our approach, a comic consists both of "normal" comic frames, and of frames that allow interaction. These interactions (typically decisions) lead to specific narrative threads and outcomes. The comic is drawn automatically, and the story is told gradually as the learner engages with the interactive frames. Thus, students generate their own stories depending on their decisions. The learner can even experiment with intentionally wrong decisions (e.g. by wilfully providing a calf with unhealthy first milk) to understand the negative consequences without real animals being harmed.

Learners can change their decisions and observe alternative outcomes in the interactive comic. A storybook is generated to summarize learning experiences and achieve the goal of a mistake-free final comic.

Interactive comics (or game comics) are not yet sufficiently understood with respect to interaction and algorithmic storytelling, let alone in the context of a learning system (Goodbrey, 2017). As described by Neo and Mitchell (2016), there is still a conceptual gap between interactivity and narration. Therefore, we have to choose cautious steps in our project that allow for early testing and fast development of prototypes.

3. Methods

For the creation of the comic, we are developing the concepts for the interaction logic, algorithmic story generation (the 'Story Engine'), and visual representations. In order to be able to set foot on the ground despite the complexity of the remaining open questions, we are currently anchoring our ongoing ideation process in linear stories and devising interactivity from there. First, we summarise the latest relevant content from the area of animal welfare, and didactically reduce it to its core.

The content is then put into a linear comic with illustrations that represent a "happy path" (Figure 1) on a farm. A happy path means here that all decisions in the story are correct regarding animal welfare. The "happy path" is then expanded to form a decision tree that branches out at the critical points of the story. This leads to interactive narrative threads. The result is a comic strip with a main "happy path" and branching stories, including “unhappy paths” (Figure 2). Note that this process and structure are a methodological step within the ideation and evaluation process and it still needs to integrate the final interaction design and algorithmic story control.

At the moment, branches are created where a wrong decision can be made or unexpected events occur. This lays the ground for the interaction of the learners.

We are using Unity game engine in a 2021 version, along with the Panoply plug-in for comics. However, Panoply's flexibility for dynamic comic creation is currently in doubt, and we may consider replacing it with our own control modules.

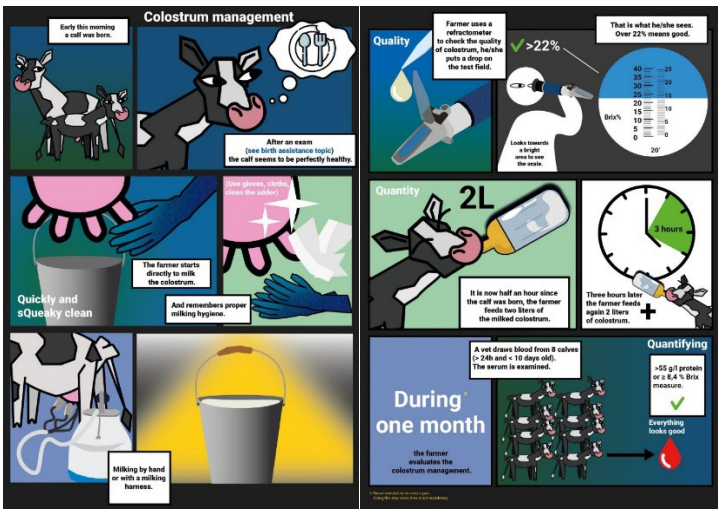

Figure 1: Happy path of the colostrum management comic

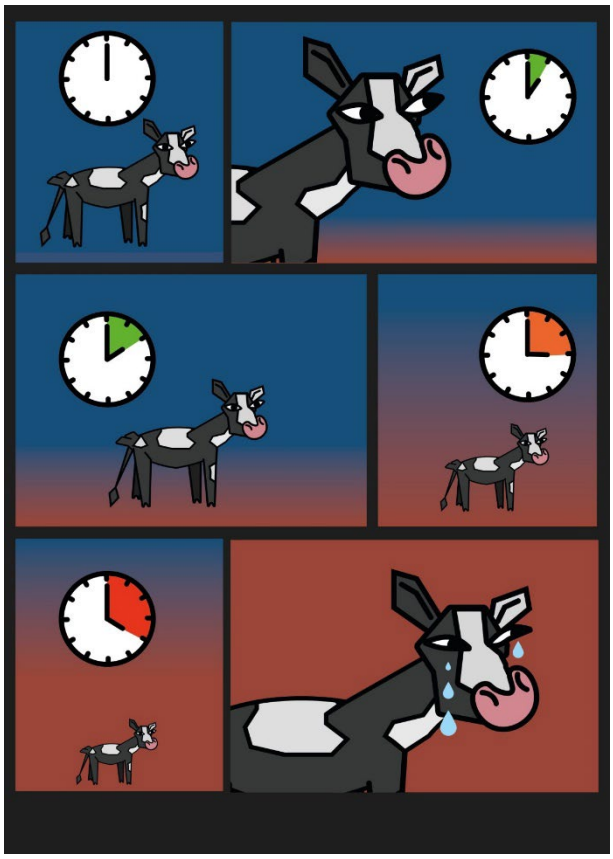

Figure 2 Example of unhappy frames

In order to successfully convey the learning objectives, it is of great importance to show negative results in the area of animal husbandry. What are the consequences if a calf receives too little, too late or inadequate colostrum (first milk)? How can the consequences of different choices be presented to each learner without monotonous repetition and over-complex implementation?

The format of an interactive comic promises, with comparatively little effort and introduction, to generate systematically different narrative threads with different outcomes. Several conceptual questions of the Comic Automaton are still under analysis. For example, it is not clear at this moment whether the Comic Automaton should take the learner back in time to branching points in order to allow correcting a wrong answer or if we should instead add a new storyline with a repetition of the previously quest in case of a previous bad decision of the learner, in order to allow making it right, without erasing the past.

Regular workshops with the target group are conducted to test ideas, concepts, and prototypes. Two different precursors of the Comic Automaton were evaluated in a workshop by means of an established User-Experience-Questionaire (UEQ) according to Schrepp et al. (2014), qualitative questionnaires and brainstorming. In the UEQ, Prototype A (classic learning game) performed particularly well in perspicuity and efficiency, whereas Prototype 2 (learning machine) performed better in attractiveness, stimulation and novelty. It should be noted that only novelty showed a significant difference by means of a T-test. The state of the Comic Automaton presented in this paper will be tested for ease-of-use and usefulness in another workshop in the fall.

Undergraduate students are currently developing storylines for the Comic Automaton alongside the core team. Integrating the students into the conceptual processes exemplifies our efforts to involve the target group in the higher education curriculum.

One of the potentials of employing comics as a starting point lies in the simplicity of providing additional background information side-by-side with the main storyline. For example, concerning colostrum management, we can add frames explaining the consequences of drinking colostrum for the calves' body.

We simply draw a glassy calf (Figure 3) to visualise abstract biological processes within the comic and in its style.

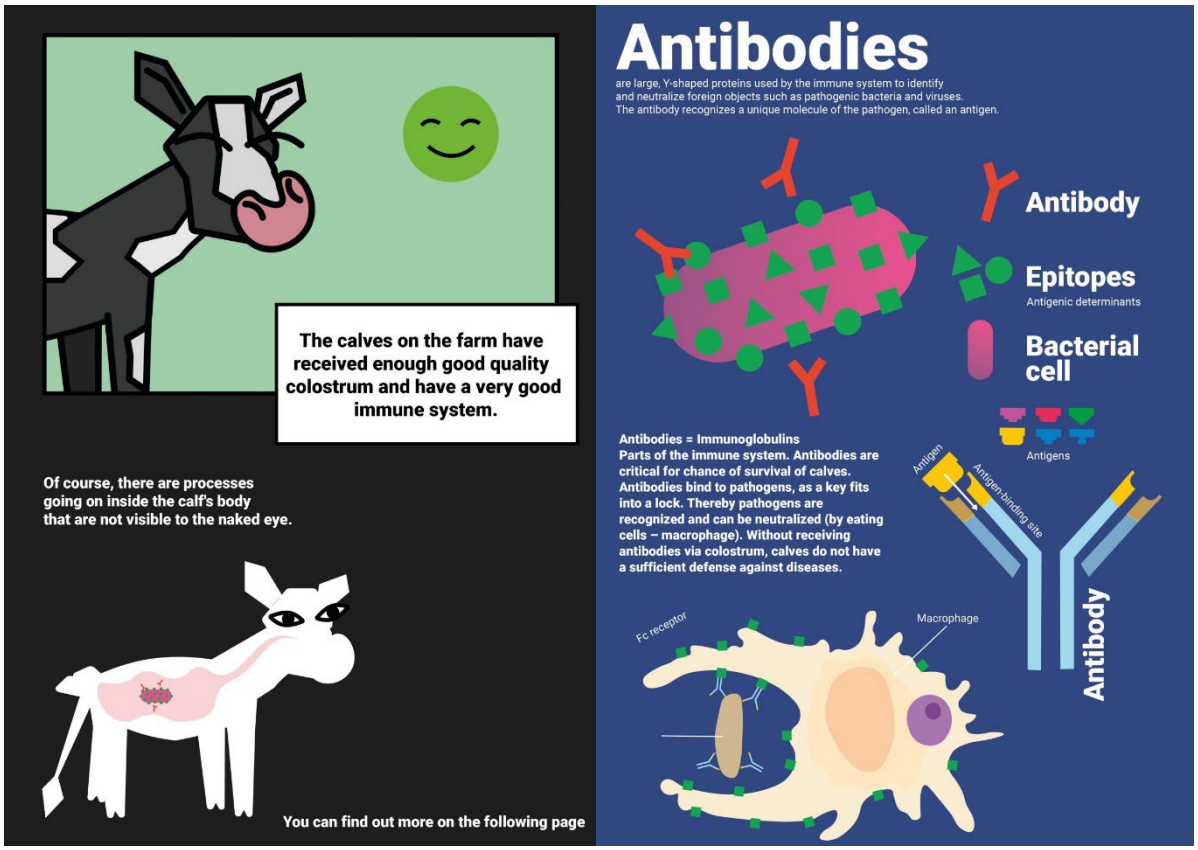

Figure 3: Information beyond storytelling

Figure 4 Using paper-prototypes for development

4. Conclusion and Further Approach

We are sure, departing from the workshop results and our conceptual work, that a Comic Automaton is a most promising approach to convey decision-making processes and courses of action in the domain of animal welfare, but certainly for a multitude of other areas as well. The conceptual framework for the interaction and learning path design, which sets the order and content of comic frames, is still being developed. The next step involves creating a Story Engine module for the automatic generation of the interactive comic

Acknowledgements

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Virtual Chemistry Exam Preparations Designed as Escape Rooms

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Abstract: Chemistry is a very interesting but sometimes for students too theoretical and therefore strenuous topic with a lot of theoretic basic knowledge to be memorized. This can lead to lacking fascination during lectures. In laboratory work chemistry often seems more tangible. In order to enhance the student´s interest for chemistry already for the theoretical basis, new ways for teaching but also exam preparations are being designed. In our work we want to focus on an innovative way for exam preparations combining the theoretical knowledge from the lecture and the practical experience from chemistry laboratory work in a game-based elearning setup. The idea is that in a game-based way students are more motivated to activate their knowledge by solving different tasks. They can combine information and try out various possibilities to find the solution or use additional help (e.g. links to theoretical input). On top, they get direct feedback if their answers are correct. The exam questions are found in a virtual chemistry laboratory. Not only theory questions have to be answered (e.g. by using multiple choice, drag and drop, …), for other tasks virtual chemical experiments (without any danger!) will lead to an answer. Usually a code (numbers, letters, signs, …) has to be obtained which is necessary for continuation. By solving different questions and chemistry tasks, the participants will be able to complete the exam preparation test and to exit the designed Chemistry Escape room with the planned name "ChemScape". Right now, a virtual chemistry laboratory is designed and already some chemistry questions from lecture exams are inserted and implemented in the escape room game. First tests with students will follow until summer. As already another chemistry Escape room station with real materials (solutions, instruments, …) has been tried in different settings – always receiving good marks and enthusiasm for fun, entertaining and good imparting of knowledge, also a virtual Chemistry Escape room game is expected to be well accepted. Gamification is often a very good way for motivation – it can even convert boring seeming topics into real fun and interest and the will to learn more!

Keywords: Chemistry, e-Learning, Exam preparation, Virtual laboratory, Digital scientific escape rooms

1. Game-Based Learning

The usage of game-based learning (GBL) has evolved in the last decades as it showed very positive effects for education. It works with physical - (e.g. puzzles, cards or other objects to play with) or digital (on a webpage or in an application for mobile devices) or can be a mixture of both. Including educational games and simulations, GBL has been stated especially promising in higher education (Crocco et al, 2016).

One game type in GBL is known as "Escape games". There, players, locked in a room, have to escape by finding hidden items and solving a sequence of puzzles. The subcategory "educational escape games", defined as "an educational approach which uses a game format in which students participate in a series of activities designed to acquire knowledge or skills, linked to learning objectives, by solving a series of puzzles in a given period of time" (Soares et al, 2023) are developed for certain participant groups and have deliberately specified learning goals (Veldkamp et al, 2020). For the learning field medicine Soares et al (2023) describe its usage for surgery training, Hermanns et al (2018) for pharmacology and Molina-Torres et al (2022) for training anatomy.

Hermanns et al (2018) line out, that the designing of escape room tasks is challenging, as tasks have to align with the curriculum, avoid boredom and frustration and have to use a special form of questions as often numerical or alphabetical codes have to be obtained.

Escape games can take place in real environments or can be designed in a virtual manner. In both settings participants must get active, search for puzzles, hints and helpful materials in order to solve the tasks and finally find the way to leave the room.

2. Project "ChemScape"

2.1 Idea

As mentioned above, different escape room games can already be found in literature in the field of medicine. For chemistry, however, at the moment, there are not many publications – especially not for digital escape games. In text format, an educational homepage offers a chemistry escape room to escape a secret laboratory. (https://unterrichtsheldinnen.de). Peleg et al (2019) describe an adaptable, movable chemistry escape game with experiments to be solved with simple chemical materials and reactions in a real chemistry laboratory. The publication of Monnot et al (2020) reports about adopting escape rooms to large audiences in chemical

engineering and giving the possibility of playing the game in real scenes or on a digital medium. A 2D chemistry escape room with a virtual laboratory on the starting homepage has been created by the German Chemical Society (https://jcf.io) - all tasks, though, are described for performing the experiments in a real laboratory.

In contrast to the above-mentioned chemistry escape room games, in our work, we describe the creation of a digital escape room game for chemistry in 3D. So, in the game it will be possible to grab and move objects and to virtually perform laboratory experiments which will enhance the realistic character. Advantageously the game can be played without the necessity of a real chemistry laboratory environment.

2.2 Purpose and Expectations

The particular purpose for the design of a 3D digital chemistry escape game is enhancing interest, understanding, knowledge and, as a consequence, the grades of students in chemistry exams, and therefore additionally providing them with a better knowledge base for natural science or engineering courses connected with chemistry. Also, logic chemical thinking and problem-solving ability for chemical questions should be enhanced. Furthermore, as escape room games are known to be collaborative, task-oriented, time-based and provide immediate feedback, they are motivating and attractive for in-class learning activities (Nicholson, 2018).

In that manner, the "ChemScape" digital escape room game should turn out to be a good way to solidify chemical knowledge, to gain new information, to combine chemical theory in a new manner – also by applying chemical experiments in a digital form, easy and without any danger - and to prepare for chemical exams.

As already a real scene chemistry escape room scenario (with real liquids, instruments and other materials) has been established and tested out in different settings at the University (e.g. as part of a treasure hunt for student visitor groups or as one escape room scenario together with others at a research night event on the campus) – always receiving good marks and enthusiasm for fun, entertaining and good imparting of knowledge - also a virtual chemistry escape room game is expected to be well accepted.

2.3 Time Schedule

The presented project started in the first quarter of 2023. At present, a virtual chemistry laboratory has already been designed and some chemistry questions from lecture exams have been inserted and implemented in the digital escape room game. More questions are already selected to be programmed and designed for the game and further tasks will be continuously implemented until summer. Then, also first tests with students will follow and the learning analytics will produce first feedbacks about the chemistry tasks and what could be rearranged and improved. The "ChemScape" will then also be implemented step-by-step in chemistry lectures.

2.4 Methodology

After not finding any literature on the implementation of chemical competencies into an universally available virtual escape room, our approach is empirical. The problem of students inadequately preparing for exams due to low motivation is intended to be solved through gamification. However, the problem with gamification is that typically a separate game would need to be programmed for each subject matter, which is a labor-intensive task. Our approach is to design a flexible escape room where questions can be dynamically entered through a CMS (Content Management System). The setup of the room remains unchanged. Therefore, from a didactic perspective, it is necessary to assign each individual competency to one or more suitable door-openers. Depending on the required competencies, a game with the necessary skills is then dynamically generated (see Figure 1). Necessary improvements to the game will be prompted through written feedback from both students and professors.

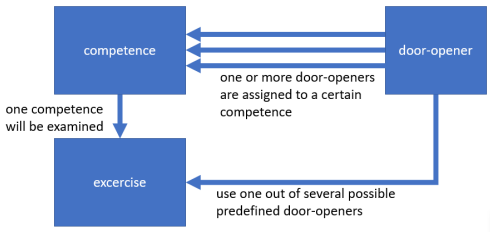

Figure 1: Dependencies of exercises, competences and door-openers

2.4.1 Requirements

Since it is an online game, both the creators of the escape rooms (professors) and the players (students) only need an internet connection and a common browser that supports Unity, such as Google Chrome. No additional plugins are required.

2.4.2 Game setup

The "ChemScape" escape game is designed as a virtual 3D laboratory with programmed virtual furniture (mainly laboratory benches, cupboards, fume cupboards, sinks and some safety establishment), equipment as cleaning facilities, analytical instruments (e.g. balances) and a big variety of chemical glass ware and paraphernalia. Figure 2 shows an example of a virtual designed chemistry laboratory room with different instruments, glass ware and laboratory furniture. 1a is a free template from "Unity 3D", 1b shows a working place in the "ChemScape" laboratory with a four-digit door-opener (in red circle) at the current work progress.

Figure 2a: A virtual chemistry laboratory (free template from "Unity 3D" (https://unity.com/de))

Figure 2b: Working place in the laboratory at the current work progress with a four-digit door-opener (in red circle)

For the designing phase, different types of measuring instruments, as for example balances or pH-meters, have been photographed in real chemistry laboratories on the campus and are currently at the stage of being designed. Figure 3 shows an example for virtually designed glass ware, pipetting aids and an analytical balance. In the shown analytical task correctly pipetting of volumes shall be practiced.

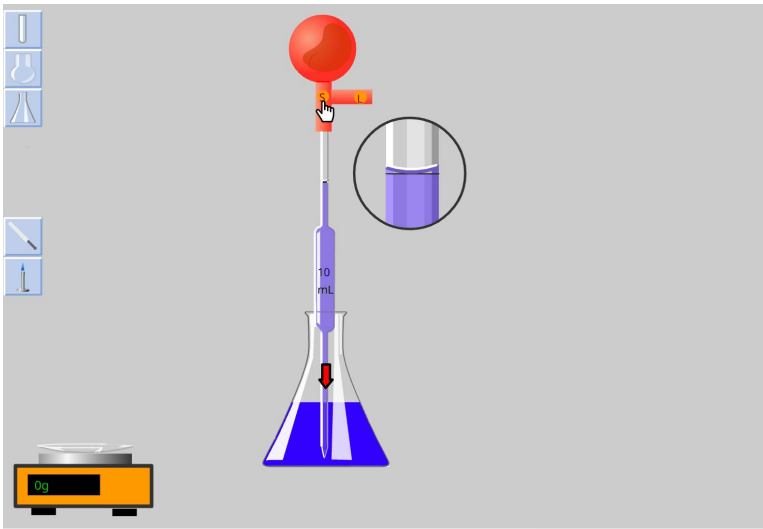

Figure 3: Example of an analytic task (here correct pipetting of liquids)

The special feature of the instruments will be their realistic way for usage. In order to use the instrument, it will be necessary to do the same handling procedure as in a real chemistry laboratory. This means for example

inserting the pipette in the liquid, pushing the button "S" at the pipetting aid for "sucking liquid" and stop the sucking process exactly when the meniscus of the liquid is at the line mark.

The different chemistry tasks will cover theoretical knowledge from the lecture as well as associated laboratory experiments. They will either be directly present at the virtual laboratory working place, preferably shown as images, or will appear somewhere after solving the previous question. Figure 3 shows a task example where the participant should understand that liquids should be sorted by increasing pH.

Figure 4: Task shown as image for a sorting of liquids by increasing pH

Materials (as e.g. vessels with chemical substances), hints (e.g. a colour code) and useful things (e.g. diagrams, the periodic table, ...) will be close or at the work place – either obvious or hidden (e.g. behind boxes or in the cupboard).

In order to continue (go to the next task or leave the room), we have until now programmed 10 different methods for opening a door of a box, a drawer, a bag or other storage containers where an item necessary for the next task (e.g. a scale or a sheet with the next riddle) or the key to exit the room will be found. Table 1 lists our 10 door-openers.

Table 1: Types of door-openers

No.	Door-opener
1	Bring images into a certain order with drag and drop
2	Type a code into a display with the form of the Periodic table of Elements
3	Select one test tube out of 10 and put it in the right slot, then press a button
4	Single-choice slot: select the right option in four different slots ("one-armed-bandit")
5	Weigh a certain amount of substance on a scale and put it in a box
6	Slider: bring four sliders into the right position
7	Pipette: get the right amount of a liquid and transfer it into a box
8	n:n cable-connection for assignment (e.g. name to formula)
9	Create a certain amount of gas through a chemical reaction (e.g. weigh in $CaCO_3$ and put it in a vessel of HCl)
10	Drag & drop different objects (e.g. metals and non-metals) and sort them into boxes

From the didactic point of view, we assigned for every competence that is necessary to pass the exam at least one door-opener.

As an example, figure 5 shows an image task for the competence "electron configuration of chemical elements" that uses door-opener 2.

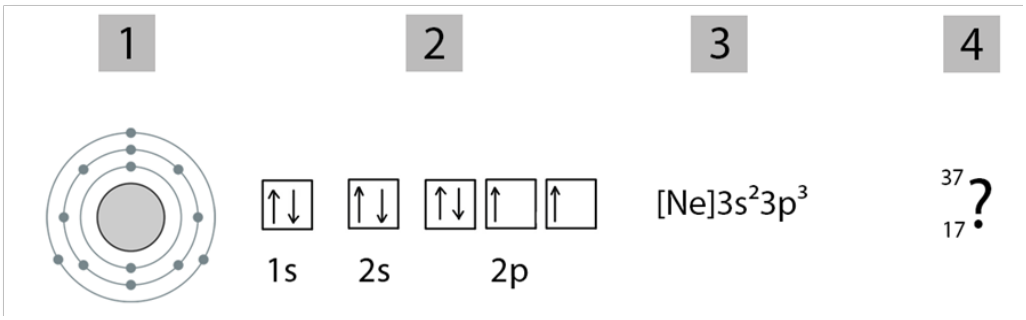

Figure 5: Example for an image task in "ChemScape"

The solutions to the elements of the above task (Al, O, P and Cl) will have to be clicked in the door opener designed as a (reduced) Periodic table of elements (Figure 6).

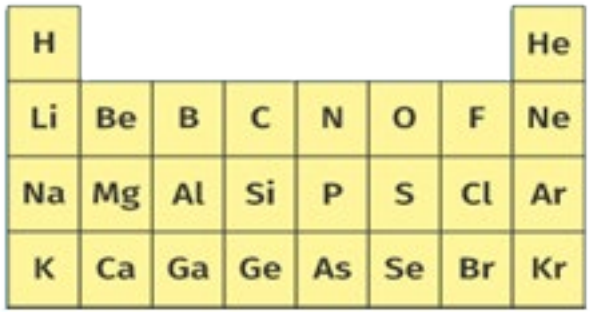

Figure 6: Periodic table of elements for clicking the correct elements to pass the task

Another feature will be the possibility (maybe in form of a small figure or a button) to request help (further information for the task or theoretical background).

It will be possible to choose whether experiments or answers can be redone (one or more times) before the results are finally inserted and checked.

2.4.3 Technical setup

All objects are created with a 3D-engine called "Unity 3D" (https://unity.com/de). The whole game runs as web-application. The user-frontend will be a simple website based on php, html5 and javascript. Questions, tips, equipment, and behaviours of the objects are inserted in a mysql database via a content management system and can be extracted dynamically depending on the respective exam. For each problem, it is possible to assign up to three tips.

2.4.4 Learning Analytics

In order to evaluate the difficulties of the questions on the one hand and the way how the different tasks are being solved by the game players, the examiner assigns a code to the candidates, which can be used to identify the students, allowing the examiner to access the results (number of failed attempts, number of hints used, duration of the game). Furthermore, these data collected by all students should be used in the future as a measure of the difficulty level of a question.

Figure 7 shows an example of a learning analytics result how it could look like when implemented in the escape room game. In the example demonstrated six participants processed up to eight different chemistry tasks (shown as question numbers).

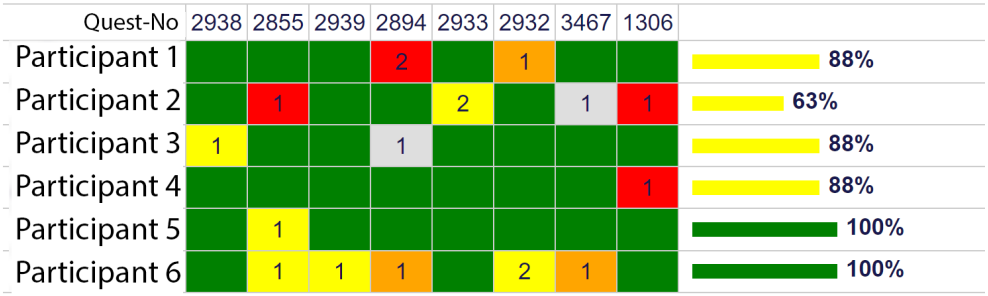

Figure 7: Example for a learning analytics evaluation of chemistry tasks

A green color means that the respective task has been solved the first time. Yellow signals that the task was solved after failed attempts (the number shows the attempts). Orange marks mean that the respective task could be accomplished after examining the solution approach. Participants with green, yellow or orange color marks could achieve 100%. Red shows that despite understanding the solution approach, the task has not been accomplished yet. In this case, only less than 100% could be achieved. This was also the case in the example where there were still grey marks – signaling that these tasks have not been processed yet.

2.4.5 Evaluation

An evaluation of the escape room game will be done on different expansion stages of the programming and introduction of the game. Feedbacks from participants and professors will help to further improve the game.

3. Conclusion, Discussion and Outlook

The design of a 3D chemistry escape room is challenging – especially as it should also be used as exam preparation tool. But it will be an innovative and useful tool in chemistry courses once a variety of different chemical tasks have been invented and programmed.

After the release of the game, we want to evaluate two aspects: First, an evaluation from the students' side regarding comprehensibility, fun factor, difficulty level, and user-friendliness. Second, an evaluation from the chemistry professors' side regarding improvement in learning outcomes compared to a control group.

As a follow-up of the basic version, more questions, tasks and problem-based learning situations will be designed in following projects.

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Serious Game For Training to Escape from Disasters and Deal with Accidents

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Abstract: The purpose of this study is to consider training methods to increase the ability to respond to disasters and accidents, conduct experiments, and verify their effectiveness. Based on this method, we decided to develop a serious game. The serious game developed in this project focuses on learning how to respond to disasters and accidents. Players encounter disasters and accidents in their daily lives. Consequently, the protagonist is portrayed as having bad luck and experiencing various unfortunate events. To facilitate learning, a time limit is set, and the time limit is extended to encourage players to continue playing. Specifically, the game begins with a fortune teller informing the protagonist that they will face an unfortunate event, and if they do not successfully navigate it, they will die within a month. If the protagonist overcomes the event, they will receive a lucky item. Collecting ten lucky items will extend their life by one month. To motivate players, unique and numerous lucky items are provided to encourage continued play. To give players an incentive to play the game, we decided to provide unusual lucky items and numerous lucky items to encourage them to continue playing. To verify the effectiveness of this game, a control group experiment will be conducted at the end of the game development.

Keywords: Serious game, Learning

1. Introduction

Japan is a region highly susceptible to earthquakes, often resulting in severe damage. Examples include the Great Hanshin-Awaji Earthquake in 1995 and the Great East Japan Earthquake in 2011, both of which led to significant destruction. The extent of damage varies by region; for instance, fires caused the most harm during the Great Hanshin-Awaji Earthquake, while the tsunami was the most damaging aspect of the Great East Japan Earthquake.

In addition to major disasters like earthquakes, numerous everyday accidents have occurred in recent years, leading to minor injuries and occasionally necessitating emergency medical treatment. According to data from the Disaster Prevention and Safety Division of the Disaster Prevention Department of the Tokyo Fire Department, the number of individuals transported to emergency services between 2014 and 2018 increased annually, reaching 144,548 in 2018, the highest figure in the past five years. Approximately half of these accidents took place in residential buildings and other domestic locations.

The aim of this study is to propose training methods that enhance the ability to respond to disasters and accidents effectively.

2. Serious Game

2.1 Serious Game

Serious games are simulation games that address real-world issues, such as natural disasters, with the goal of mastering abilities beyond mere game completion. The term "serious games" originated in the United States around 2002, emphasizing the importance of achieving goals outside the game.

2.2 Related Research

Serious games have been employed in various domains, with cases where competence has been increased through training and education. Disaster risk awareness, the understanding of the dangers posed by disasters when they occur, has been targeted by researchers. Urano et al. developed a game system that allows individuals to learn about disaster risk while having fun and practicing disaster drills. The evaluation experiment confirmed that the system improved disaster risk perception. Kikuchi et al. developed a serious game for preliminary learning of evacuation behavior during disasters and verified its learning effectiveness. Comparative experiments with text-based learning showed that the game's learning effect was slightly inferior to text-based learning, but the game's inherent features made learning enjoyable, and learning outcomes could be further improved by increasing the allocation of game elements.

3. Games Development

3.1 Methodologies

Caserman et al . assert that a serious game consists of a serious part and a game part, and maintaining a balance between the two is crucial. In the serious part, ensuring the accuracy of learnable knowledge and providing appropriate feedback are important. In this study, the accuracy of knowledge is ensured by creating learning materials from specialized books and other sources. Additionally, for each action the player selects in the game, it is presented whether the action was correct and an explanation is provided regarding the appropriateness of the chosen action.

In the game part, it is essential to provide players with an incentive to play and a mechanism for continued gameplay. Rewarding players for making correct choices and offering unique items that cannot be found in everyday life should motivate players to engage with the game. Also, offering a large number of items and designing the game to encourage collection can promote continuous play.

3.2 Game Background

The serious game developed in this project focuses on learning how to respond to disasters and accidents. Players encounter disasters and accidents in their daily lives. Consequently, the protagonist is portrayed as having bad luck and experiencing various unfortunate events. To facilitate learning, a time limit is set, and the time limit is extended to encourage players to continue playing. Specifically, the game begins with a fortune teller informing the protagonist that they will face an unfortunate event, and if they do not successfully navigate it, they will die within a month. If the protagonist overcomes the event, they will receive a lucky item. Collecting ten lucky items will extend their life by one month. To motivate players, unique and numerous lucky items are provided to encourage continued play.

3.3 Game Operation and Overall Flow

The game begins when the player presses the "Game Start" button. An introductory video explains how the main character met the fortune teller and presents the game settings to the player. The game starts with the player character waking up in the morning at home. A tutorial screen is displayed, explaining the game controls. Specifically, the 'W', 'A', 'S', and 'D' buttons are used to move the character, while the 'E' button displays the in-game player character's smartphone screen. The 'I' button provides a list of lucky items acquired so far.

The game's flow, as shown in Figure 1, involves the protagonist experiencing various unfortunate events, with the player choosing a response from a list of options within a limited time frame. If the correct response is chosen, the player receives a lucky item; if not, the player loses life points. The correct response and its explanation are also presented at that time. Depending on the player character's location, various events will take place. Throughout a month, there are a total of 15 opportunities to obtain items.

After the tutorial, the player character's smartphone alarm sounds. Simultaneously, the screen displays 'Press E to see your smartphone'. When the player presses the E button, the smartphone screen shows 'I'm leaving now', and the player moves to the front door.

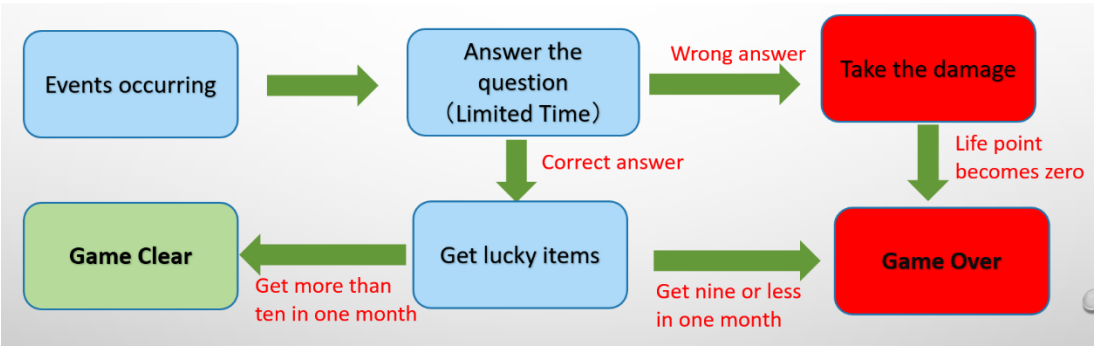

Figure 1: Game Flow

Upon approaching the front door, the 'Destination' selection screen appears, allowing the player to choose between 'home, school, shopping street, park, mountain, or beach'. In this case, a "!" is displayed at the location of an event. The player can select a destination by hovering the cursor over it.

If the player selects 'Home', the question "Would you like to spend the day at home?" is displayed, and selecting 'Yes' returns the player to the room. If there is a house event, the event will occur. If there is no event, the player is free to spend the day at home. When approaching the bed, the player is asked, 'Do you want to end the day?', and if they select 'Yes', the day concludes.

If another location is chosen, the player is teleported to that location, and an event occurs if applicable. If there are no events, the player is free to explore the chosen location. To return home, the player must go back to the teleportation point and select 'Go home'. The events occurring in the game and their locations are listed in Figure 2. There are two bonus events, during which players are guaranteed to receive lucky items.

Order of events	Incident	Location
First	Locked in an elevator	Shopping district
Second	Mercury products cracked	School(laboratory)
Third	A person was found with a broken bone	Mountain Trail
Fourth	A student drowned (knowledge of cardiac massage).	Beach
Fifth	Park Cleanup (Bonus Event)	Park
Sixth	A lens-effect fire	Home
Seventh	Heatstroke	Park
Eighth	My friend's throat got stuck	School(Classroom)
Ninth	Prevention before typhoon	Home
Tenth	Walking on the beach (Bonus Event)	Beach
Eleventh	Fire Evacuation	School
Twelfth	The stampede	Shopping district
Thirteenth	Bites from poisonous insects	Park
Fourteenth	Oil pan on fire	Home
Fifteenth	A fallen man was found (Knowledge about the use of AEDs)	Shopping district

Figure 2: In-game events

3.4 Game Demo

Next, I'll choose one of the above events to demonstrate how the game works.

Figure 3 show the game event as the 'oil pan ignition.' The ignition is caused by the oil temperature being too high. Using cooking utensils with safety features, such as stoves equipped with overheat protection, can be effective. However, most importantly, once the stove is lit, it is crucial never to leave it unattended.

The event begins with the player controlling the character and moving to the front door. By selecting 'Kitchen' from the map list, the player is teleported to the kitchen. Following that, a conversation UI is displayed, as shown in Figure 3. The text on the picture should read: 'What should I have for lunch? Let's make tempura. '

Figure 3: Game event

After the conversation begins, the player is tasked with making tempura, and a pot appears on the stove. Approaching the stove, as shown in Figure 4, triggers the ignition of the oil in the pot. The text on the picture should read: "The oil temperature is too high, and the pot is on fire. What will you do?" The choices are "Cover the pot with a lid" and "Pour water into the pot."

Figure 4: Above Event Question

The correct response for this accident event is to "Cover the pot with a lid." The reason is that this can extinguish the fire by cutting off the air supply. Using a wet sheet, bath towel, or similar items instead of a lid can also be effective, but there is a risk of reignition if the cover is removed too quickly. Therefore, it's important to wait until the oil temperature has sufficiently cooled down. In the case of a correct response, the fire will stop, a lucky item will appear, and the player can collect the lucky item.

4. Game Validation

First, before conducting the experiment, the subjects are given a small test about responses during accidents or disasters. This test aims to assess the participants' current knowledge of the topic. After completing the test, their scores are recorded. The test consists of a total of 10 multiple-choice questions, all related to accident events that occur within the game. The test questions are provided in Figure 5.

Q1. When trapped inside an elevator, what is the correct course of action?
A. Tap on the elevator door
B. Press all the buttons for different floors
C. Climb up the elevator shaft to inspect the cause of the malfunction
D. Stomp your feet in the elevator
Q2. What should you not do when a mercury product breaks?
A. Open windows to ensure air circulation
B. Sweep up the fragments with a broom
C. Wear gloves and collect the fragments
D. Evacuate the crowd
Q3. When dealing with a fracture, what should you not do?
A. Transport the injured person directly
B. Observe the wound to determine the type of fracture
C. Immobilize the fractured area
D. Stabilize the injured person
Q4. How many compressions should be performed in one minute during cardiopulmonary resuscitation (CPR)?
A. 80-100 B. 70-90 C. 100-120 D. 120-140
Q5. In which season is house fire most likely to occur?
A. Spring B. Summer C. Autumn D. Winter

Q6. What is the name of the rescue method when someone is choking?
A. Kremlin Emergency Method
B. Ihumrick Method
C. Heimlich Maneuver
D. Muhairrick Method
Q7. What should you not do if you encounter a train accident?
A. Bend down to pick something up
B. Leave the scene immediately if something like that seems likely to happen
C. Look for something hard
D. If you accidentally fall, lie down sideways.
Q8. What should you not do after being stung by an insect?
A. Wash the wound
B. Take a photo of the venomous insect
C. Cut open the wound to remove the venom
D. Go to the hospital
Q9. What should you not do when a pot catches fire?
A. Put water into the pot to extinguish the fire
B. Cover the pot with a lid to extinguish the fire
C. Turn off the gas stove
D. Put a wet cloth over the pot
Q10. What is incorrect about using an AED (Automated External Defibrillator)?
A. Touching the patient during heart rate analysis
B. Moving away from the patient during defibrillation
C. Performing CPR on the patient before using the AED
D. Performing CPR on the patient after using the AED

Figure 5: Test Qu Question

Following the test, the subjects are asked to play the game, and after finishing, I will record their gameplay results. Subsequently, they will respond to a questionnaire regarding the game. I will ask questions from various domains and draw conclusions from the questionnaire's outcomes. The questionnaire's contents are as outlined in Figure 6.

① Survey about Increased Knowledge of Relevant Information:
1. After completing the game, my knowledge about everyday life accidents has increased.
2. There were many things I didn't know before.
3. After finishing the game, I feel well-acquainted with the specific applications of the related knowledge points.
4. I believe that in the future, I can solve similar problems effectively.
② Survey about Superiority Compared to Other Training Methods:
1. Studying within the game was more engaging than using books.
2. Studying within the game provides a greater sense of presence compared to studying from books.
3. Training methods within the game are more diverse compared to real disaster preparedness training.
4. I didn't experience much motion sickness (3D sickness) during game progression.
5. I was able to learn while enjoying the game.
③ Survey about Enjoyment of the Game:
1. Did you complete the game?
2. When playing the game, did you actively think about the problems?
3. It was enjoyable to collect lucky items in the game.
4. I felt happy when I obtained a lucky item I had never seen before.
5. The game was fun.
6. If there were similar games, I would like to try them again.

Figure 6: Questionnaire after the experiment

Finally, the test is administered once more, and the results of the two tests are compared, alongside the questionnaire responses. This combined data will be used to evaluate the effectiveness of the game.

5. Summary

The purpose of this study is the development of a serious game aimed at enhancing response capabilities to disasters and accidents. Through investigation and analysis of related research and existing games, considering the background of the planned serious game and the flow of the game, all the scenarios for accident events within the game and the game stages have been completed. Furthermore, the implementation of necessary game systems and accident events within the game has also been finalized. Looking ahead, bug resolution within the game and improvements to the questionnaire will be conducted. Subsequently, subject experiments will be carried out to validate the effectiveness of the developed serious game.

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Challenges in Designing a Game for the Prevention of Intimate Partner Violence

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Abstract: In this report on our ongoing work, we present initial findings from the development of a serious game to support primary prevention of intimate partner violence (IPV). We discuss educational goals and game mechanics ideas to address specific challenges that arise from conflicting implications for design of this issue.

Keywords: Serious game design, Intimate partner violence, Awareness game, Games for social change

1. Introduction

This contribution reports on our ongoing development of a serious game to support primary prevention of intimate partner violence (IPV). The work presented concerns specific aspects of game design within an interdisciplinary project with experts on IPV. There is a strong taboo and many misconceptions about this critical social issue, and the learning objectives of the game are to reduce these through education and empathy. During the design process we were challenged by the sometimes conflicting goals associated with this specific, complex issue. A balance had to be found between abstracting the subject to ensure playability and risking oversimplification that could lead to unintended messages. Below we outline these challenges and our approach to addressing them, and present the resulting mechanics and narrative structure of the game.

2. Related Work

Games on IPV are rare, mostly from academia, with a focus on sensitising players to recognise forms of gender-based violence, or on evoking empathy with victims of sexist, controlling or violent behaviour (Yañez et al. 2023). Unlike the majority of these games that deal with harassment or dating violence, e.g. None in Three (2023); Jennifer Ann's Group (2023); Cabrera-González & Florido (2020); ETC (2015), we focus on lasting cycles of abuse (Fisher & Lab 2010) in long-term adult relationships. Our own approach to the game is to have adult players explore ways to support victims of violence, overcoming intertwined relationships of a village community that protect the perpetrator (Müller et al. 2022). The game "Jesse" by None in Three (Boduszek et al. 2019) comes closest to this goal so far by depicting encounters between contacts of a family with a violent father. Beyond, games that address the adult world with its interdependencies are hard to find, one older example being the project “4Uman” (Perincioli 2023) with a clickable short story that encourages male abusers to seek violence counselling. Furthermore, discussions of issue-specific design challenges and strategies are also scarce, e.g. by Pearson et al. (2020). In our report, we therefore take the point of view of game mechanics development and focus on selected design dilemmas that arose after the necessary content research had progressed sufficiently.

3. Game Development

Our game is a single-player, point-and-click narrative adventure aimed at all adults who condemn domestic violence but are unaware of their own role as bystanders and their potential for change. According to German offender-victim statistics (BKA 2023), around 80 percent of perpetrators are male, so we decided that the constellation in our game narrative features a female victim and a male perpetrator.

3.1 Educational Goals and Vision

The game educates about circumstances of long-term abusive relationships with the structures that make it difficult for victims to find their way out of the cycle of abuse (Müller et al. 2022). It informs about the various subtle or obvious signs of abusive relationships at all stages of the cycle and addresses the obstacles that bystanders have in interpreting the signs, knowing what to do or eventually taking action. The main educational objectives are to enable players to become aware of their own role in the environment and to reflect how they can combat IPV. The game shall provide knowledge about different forms of violence (physical, psychological, social, sexual, economic, etc.), take a stand against all forms of violence, and provide information about institutional and informal offers of help. It is important to develop empathy for the situation of the victims and

the fact that it is not the victims but the perpetrators who are responsible for the acts of violence. Players should develop a positive idea of a supportive environment against violence and realise that even small offers of help are worthwhile, even if as a helper there is sometimes no direct positive or even negative feedback.

3.2 Design Challenges

As some of these objectives contain contradictions, we faced challenges in developing the game mechanics, which are explained below. The subject matter experts involved in our project warned that there are already widespread misconceptions among the public that could be confirmed by careless simplifications.

3.2.1 Challenges

"Ways out" vs. "no-way-out". On the one hand, we want to create empathy with regard to the desperate situation of the victim, and must avoid game mechanics that imply that there is an easy or predictable way to leave the abusive relationship, as this could reinforce potential victim blaming ("Why doesn't she just leave?"). On the other hand, we need to demonstrate "ways out" and encourage players to consider action.

Responsibility vs. blame. One of the goals is to highlight bystander opportunities in supporting victims and feeling responsible for an environment in which abusive behaviour is less likely to persist. At the same time, bystanders must not be held accountable for the violence, which is the full responsibility of the perpetrator. The narrative should not be limited to heroic "rescues" from violence.

Potential game breakers. Players who want to sabotage the game or simply test its boundaries must be reckoned with. The possibility that player decisions could lead to the death of the victim was considered a "no-go". Conversely, the problem of IPV should not be trivialised by harmless options or consequences, as in fact, every three days a woman dies as a result of intimate partner violence (BKA 2023).

3.2.2 Solution strategies

The project's design team first developed the core mechanics of the game, taking into account many aspects of the problem field, following a systems mapping approach (Macklin 2020) to grasp structural dependencies within the complex subject matter (Müller et al. 2022). While these basic mechanical building blocks alone would have led to overly abstract stimulus-response dynamics, it became clear that extensive narratives were needed to represent and explain different contingencies as individual variations in decisions and outcomes.

We have introduced a backward narrative (see 3.3) that begins with the worst-case scenario of the victim's death, as an unequivocal act of the perpetrator that can no longer be the result of player decisions. The players can only improve the situation afterwards by travelling back in time, and if they wanted to try out the most negative consequences for fun, the disastrous initial situation remains. This backward-looking approach should also encourage players to imagine and focus on improvements rather than oppressive prospects.

The players' task in the game is to build up a network of supporters, which in its entirety determines at the end of the game what new situation for better violence prevention in the village will be achieved. However, players need to realise that they do not have full control over the story. The success of any good or bad decision depends on situational conditions, e.g. to what extent other potential supporters can also be convinced, and is partly subject to chance. This mechanic serves two purposes. First, it avoids promoting an ideal simple action as a direct way out of a violent relationship, acknowledging that each individual's circumstances are unique. Second, it emphasises the importance of the environment as a whole without blaming any one person.

Even though our game framework mitigates the aforementioned dilemmas, we still need to keep them in mind with each narrative scene we add. Our approach involves constant testing and iteration to find the right balance in representing these complex issues in a simplified, abstract way.

3.3 Synopsis of the Game's Narrative Framework

The game tells the story of a toy village in which a murder has happened. A well renowned and popular man has mortally wounded his wife whom he has been abusing for years. Other villagers noticed signs, but there was a strong, long-established web of relationships, loyalties, and dependencies among villagers that kept them from interfering to instead maintain the taboo. Now everyone is at the funeral, desperately asking if there was anything they could have done to prevent it (Fig. 1). They ask the player to create a new reality for them.

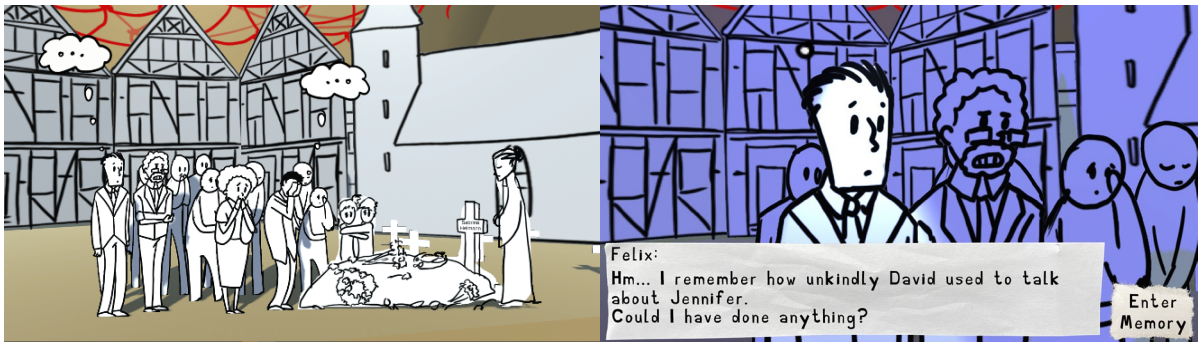

Figure 1: Screenshots: Villagers contemplating at the victim's grave

The player's task is to discover and destroy the old network that protected the perpetrator and thus facilitated the violence, and instead build a new network that counteracts IPV. This can be done by delving into the villagers' memories, revisiting for them the choices they made earlier, choosing between alternatives, and whispering in new choices (Fig. 2, left). After clicking on thought bubbles at the grave, short narrative scenes with remembered incidents are displayed as comic strips. This includes the characters' reflection about the situation, their options to act and doubts they had about them (e.g., concerns, loyalty, uncertainty, fear for themselves or the victim), and how the former situation unfolded. Then, players can decide anew. Each option leads to either positive or negative reactions from other characters, influencing the degree of network formation. Each decision's outcome is only partially predetermined and is combined with a certain luck factor. As in reality, the success of different actions is uncertain to varying degrees, such as the unequal probability of success following a player's decision shown in the wheel of fortune in Fig. 2, right. Even if the player causes a character to oppose violence, the short- and long-term success depends on the reactions of the other characters, which could depend on their mood, relationships or mindsets.

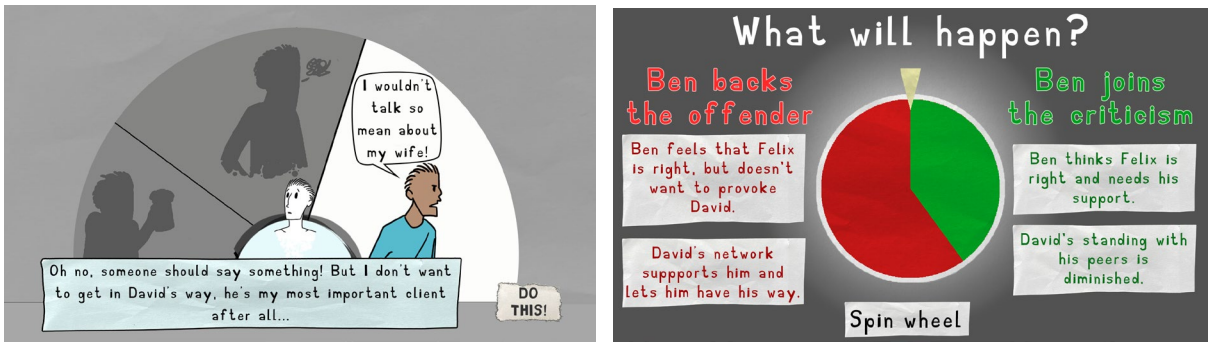

Figure 2: Screenshots: Left: Considering alternative actions for Felix. Right: After Felix contradicts the offender, the outcome of this situation also depends on how other bystanders (Ben in this case) react

After each action, feedback is given for the player's decision, including an explanation of why the resulting, partially coincidental situation occurred in the story. In cases where simply bad luck stood in the way of a successful outcome of an otherwise recommendable action, this needs to be particularly debriefed. It is emphasised that every little help is important, even if there is no direct success in every situation. It is to be expected that players will feel frustration in these cases. Since this corresponds to real-life experiences, encouraging explanations must take this into account.

After magically changing the remembered choices of the social environment, this affects the existing networks. At the end, one of several possible epilogues is unlocked through the game's actions, which describes a possible alternative future for the village in its support for potential victims.

3.4 Game Prototyping and Testing

The still ongoing game development follows iterative cycles, with first Adobe XD prototypes and transfer to the Unity game engine. We regularly adjust our design based on player feedback, which we have received so far from four formative test runs of the game with one or two memory scenes. The numbers of participants were 3, 7, 14 (each qualitative) and 47 (quantitative). Initial improvement steps concern details of the onboarding process and the user interface. In particular, it was felt necessary to include more narrative explanations as

feedback on game actions so that the indirect consequences of player decisions could be understood more instantly. The results of the fortune wheel were sometimes mistaken as “right” or “wrong” decisions, which indicates that the rationale behind these coincidental parts needs explanation. We received positive general assessments about the effectiveness of the game idea in terms of lowering barriers to thinking and talking about IPV, recognising the relevance of the topic for oneself in the role of the environment, and promoting a helpful, attentive attitude.

4. Conclusion

In this work-in-progress report on the development of a game to prevent intimate partner violence, we described the design challenges posed by specific conflicting demands and how ideas for resolving these have led to the current structure of the game experience. In the next steps, we will expand the scene pool of possible game decisions that may alter the remorseful memories of the fictional villagers. In these narrated memories, further incidents and signs relevant for partner violence will be presented, contributed by the IPV experts involved in the project based on their empirical findings. Preliminary feedback from prototype evaluations suggests that the narrative frame and mechanics of our game effectively avoid the aforementioned concerns about unintended messages. Nevertheless, we need to keep these concerns in mind as we continue to create and curate memories. To this end, we develop scene templates to speed up our iterative workflow and experiment with different configurations of scenes and outcomes to find an optimal balance.

Acknowledgements

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Fostering Self-Regulation, Motivation, and Creativity Through Gamification Software iWrite

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Abstract: Students and academics face a range of challenges when writing, including a lack of motivation, self-regulatory skills, and creativity. To address these difficulties, the Cluster of Excellence Image Knowledge Gestaltung at Humboldt University has developed a gamification writing software called iWrite. In this article, we introduce the development process of the software and its features – including gamification features such as progress bars, points, a planner, streaks, visualization, and levels – as well as additional practical writing-supportive features such as proofreading and time and activity tracking. iWrite provides valuable game features that promote the development of efficient and enjoyable writing habits. Research indicates that gamification features like these can be a powerful tool in enhancing writers' motivation and self-regulation when engaging in creative tasks like writing. While the software development is finished, a systematic evaluation of it is planned within the EU-FairPlay project beginning 2024. The study aims to evaluate consistency of usage and impact on writing progress on students testing the software over several weeks. The result is expected to show, which game mechanics are working well in context of academic writing.

Keywords: Gamification, iWrite, Motivation, Self-regulation, Creativity

1. Introduction

Writing is a critical skill that plays a vital role in academic, personal, and professional life. However, many students and academics struggle with writing tasks due to various reasons, such as a lack of motivation and self-regulatory skills (Schunk and Zimmerman, 2007). As a result, the creative outcome of the writing task may suffer due to procrastination and frustration (Ivcevic and Nusbaum, 2017). To address these challenges, educators have developed various tools and applications to improve students' motivation with game-based approaches (Bal, 2019; El Tantawi et al., 2018; Wiethof et al., 2021) In this paper, we will introduce a gamification writing software iWrite and explain how it can facilitate the development of self-regulation and motivation, which leads to better creative outcomes in writing. The game based approach has been chosen by researchers of gamelab.berlin / Humboldt University, because feedback mechanics and interactive functions from games have shown to improve motivation for longer processes with breaking them down to more motivating and rewarding units. The interdisciplinary team aimed to proof, that carefully designed game mechanics can help students and academic researchers to fulfil their writing tasks, quicker, more sustainable and with more joy.

2. The iWrite Software

2.1 Development of iWrite

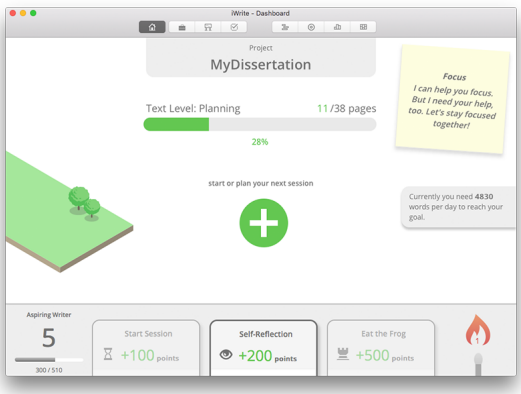

Figure 1: Startpage of iWrite

iWrite was developed at the Cluster of Excellence Image Knowledge Gestaltung at Humboldt University Berlin in gamelab.berlin. This was preceded by several years of development of the "Diary" software, which was designed to record how interdisciplinary teams work and to gain insights into how, when, and in which modes work is done. The software was able to record, categorize and visually analyze activity times and program usage. The app was developed natively in Objective-C and is available for macOS. After completing the work on it, great potential for further development was identified in the existing code base and the idea was developed to now make one of Diary's results the new objective: To support the writing of complex academic papers.

2.1.1 Problem identification

It had become apparent in the use of Diary that periods of continuous, uninterrupted, concentrated work were difficult to sustain for many academics. This was identified as one of the major obstacles in academic careers and was also described as such by the participants. The aim should therefore be to provide dedicated support for scientists working on larger textual projects such as theses, doctoral dissertations, monographs or post-doctoral theses. Such support appeared to be possible primarily through mechanisms known from game design.

2.1.2 Developmental process

The Diary project thus merged into the iWrite project at gamelab.berlin, which focuses on combining knowledge and cultural work with game design and gamification. The interdisciplinary team of gamelab.berlin interviewed numerous colleagues at the Cluster of Excellence and recorded requirements, wishes, descriptions of everyday life, problems and ideas. A game concept was developed that was based on the idea of generating motivating and descriptive feedback where there is normally none. According to the findings from the interview, iWrite should make progress visible, point out achievable milestones, give practical tips on the writing process, and create a lightweight, playful atmosphere. The team evaluated numerous game mechanics to achieve this and decided on a mix of different systems that would interlock and complement each other.

Based on the investigation and software design, the current iWrite software includes a range of mechanics and gamification features to motivate writers, including progress bar, points, planer, steak, visualization, and levels. These gamification features are align with game design elements, which are fundamental building blocks of gamification applications, featured prominently in gamification research (Zainuddin et al., 2020). Research studies have demonstrated that numerous gamification features are conducive to users' self-regulation (Li et al., 2022), motivation (Bal, 2019) and creativity (Barata et al., 2013; Xu and Hamari, 2022).

2.2 Gamification Features of iWrite

2.2.1 Progress bar

The core of the mechanic was a progress bar that appears at the edge of the screen during each writing session. This bar shows the number of words written or the elapsed time, depending on the mode. The constant visibility also gives a visible progress within the writing sessions, an achievable goal and a sense of a certain concentrated working mode that also comes back to an end. The previously indescribable sense of constant work pressure without visible progress and indefinable endpoint, is thus made concretized, definable, and visible through iWrite's progress bar.

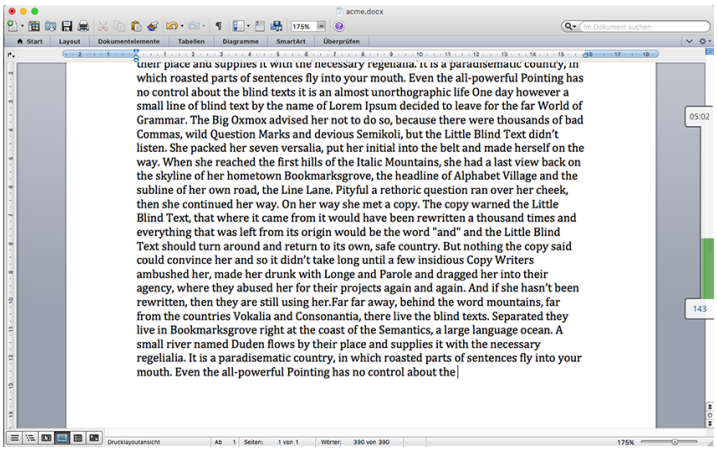

Figure 2: Progress bar of iWrite

2.2.2 Points

For each of writing sessions the user receives points according to the duration and intensity of the session. This mode is complemented by three selectable modifiers. Thus, one can choose not to take breaks within the sessions, not to activate messenger and mail programs during this time, and not to use browsers. The architecture of iWrite allows these criteria to be checked and detects violations. This increases the commitment of the users to actually comply with the criteria and builds the atmosphere of a guardian of the concentration time: iWrite is not just a tracking tool, it is also perceived as a watchdog and in some way an authority, under the condition that the writers are willing to grant such authority to the program. If one or more of the options is chosen, the achievable score per session increases.

2.2.3 Planer

This mechanic focuses on the time unit of individual write sessions. Sessions can also be set for the future, however, so that a schedule can be built up in which iWrite reminds the user of the sessions. The user thus learns to plan ahead, to find times when uninterrupted work is possible and then to use them.

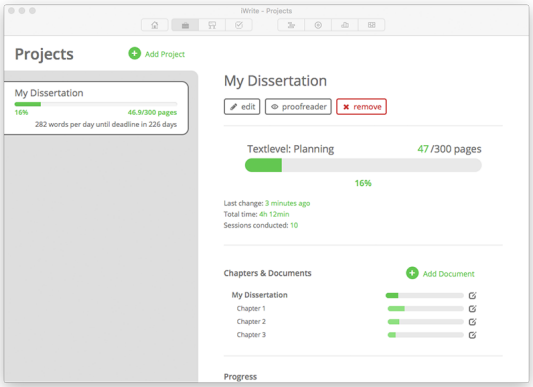

Figure 3: Project planer of iWrite

2.2.4 Streak

In order to not only plan sessions, but to perform them continuously and thus slowly habitualize them, iWrite includes a streak system. This is visualized by a flame that is always visible on the home screen. The flame gets bigger and bigger depending on the number of days on which at least one session was carried out without interruption. After three days in a row, you get a match that is also visualized. This allows one to keep the Streak if one sits out a day. In this way, the motivation of the Streak system is maintained, even if a day is not written in between. Streaks utilize the fear of losing progress as a game mechanic, as individuals are often motivated to maintain their streak and avoid losing their progress once it has been achieved. Thus, repetition over duration is incentivized and even short sessions are rewarded, which maintain the streak. Habits can be built more effectively over repetition than over long duration, which is what is being promoted here.

2.2.5 Visualization

An important factor in writing is not only the work invested, but also the text itself. For this purpose, iWrite reads Word documents, examines them for their chapter structure defined in the document and visualizes the progress in each chapter. In this way, different writing projects can be created, each with a target page number and also a target date. iWrite is then able to calculate the necessary sessions or words per day from this and thus breaks a large task into manageable parts. With the progress of the chapter, a feeling of partial completion is achieved, which supports the overall motivation.

Also on the main screen is a visualization of a house that, following the metaphor, grows from the terrain to the foundation, the shell in various construction stages to a living building. This visual progress indicator contributes significantly to making the atmosphere of iWrite perceptible as a game and to perceiving one's own text as an intellectual building. It also creates a visual reward as well as curiosity for the next visualization stage.

2.2.6 Levels

In addition to these features a level system exists for the users themselves. Linked to the progress of points across projects, users can move up levels and receive a new attribute depending on the level, such as "word gnome" or "sentence master". In this way, progress is not perceived to be lost when a project is completed, and the writing skills acquired are further incentivized. Linked to the level progress, there is also an expert tips module in which an exclusive video or a text with writing tips from alternating writing experts is unlocked per level. Level progress is thus rewarded with insights that are otherwise inaccessible. Conversely, the reception of tips is perceived as a reward and is therefore received more positively. A total of 15 detailed tips for 15 levels can be found in iWrite.

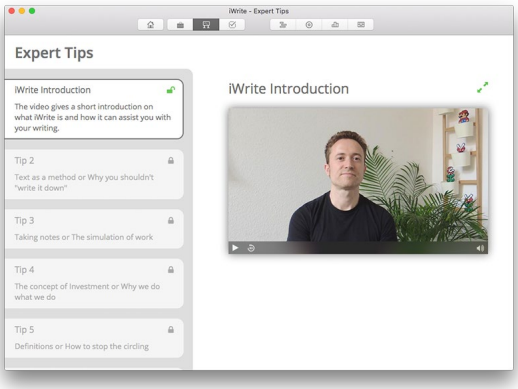

Figure 4: Expert tips of iWrite

The selection of game mechanics is rounded off by three game cards, which contain new small tasks every day. The fulfillment of the tasks also gives points. These are tasks accompanying the writing process, such as improving the writing environment, planning or correction loops, which cannot be measured directly in words or time. A card played immediately increases the score and motivates the writers in a varied way to improve the writing process as a whole.

2.3 Writing-Supportive Feature of iWrite

Beside the gamification features and game mechanics, iWrite also includes text-based feedback systems and features to support writing.

2.3.1 Proofreading

A proofreader module has been integrated that analyzes the text and gives practical tips on sentence structure, sentence length, foreign words and comprehensibility - as far as this is algorithmically possible. This generates feedback directly on the text and provides a different perspective that can help improve the text at the sentence level.

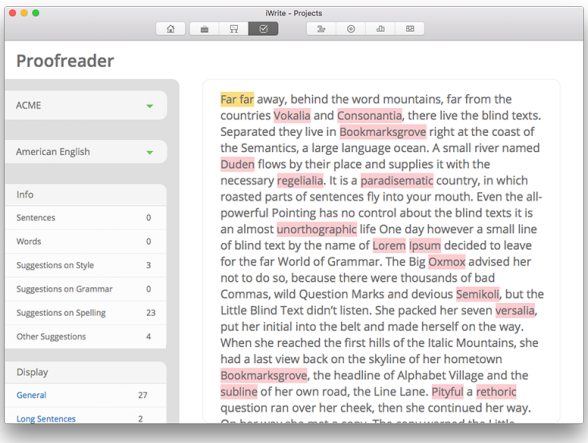

Figure 5: Proofreader of iWrite

2.3.2 Time and activity track

Diary's functionality has also been retained to iWrite to allow writers to analyze how they spend their time at the computer, when their activity times, program usage categories, and the extent to which their working practices are fragmented. This objective, non-judgmental insight creates another valuable level of feedback that helps writers better understand their own working practices, identify problems, and gradually improve practices through the provision of helpful tips and tasks.

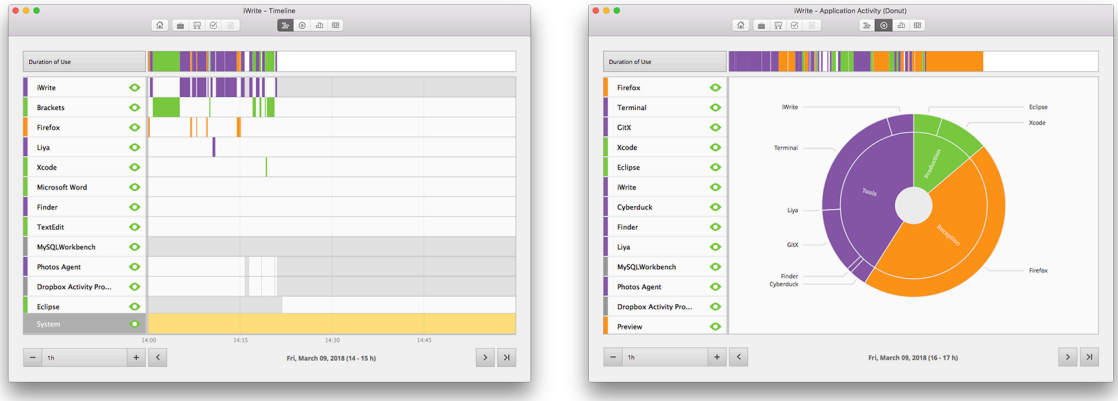

Figure 6: Time and activity track of iWrite

3. Conclusion

Taken together, iWrite includes a series of mechanics that support and motivate writers at different stages, time intervals, and perspectives to stay motivated through longer writing processes, purposefully develop writing habits, and move toward a more efficient, continuous, and enjoyable writing experience. Its development process was an iterative approach of continuous testing, interviews and development. Knowledge from game designers, computer scientists, sociologists, interaction designer, writing experts and students has been used. Tests within the cluster of excellence have shown positive adoption of the tool, and many staff members used it for their publications and provided feedback. Its use was also tested in an academic writing school at Humboldt University of Berlin. As these tests provided good first results, further and more systematic investigation is planned. For future studies, a systematic evaluation will be executed to test the effectiveness of iWrite on self-regulation, motivation and creativity within EU-FairPlay project.

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Late Submissions

Designing GBL for Higher Education: Pitfalls & Recommendations

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Abstract: Game-Based Learning (GBL) has gained significant attention in recent years as an effective educational approach to enhance student engagement and learning outcomes in higher education. This conference paper aims to emphasise the significance of GBL in higher education and presents a comprehensive review of a case study involving the application of GBL in a linguistics course. The study explores the impact of games on student learning, motivation, and engagement with the course content.By integrating gaming principles and mechanics into the curriculum, students are encouraged to actively participate, explore concepts, and apply their knowledge in a dynamic and stimulating environment. The study examines data gathered from student surveys and structured interviews to evaluate the effectiveness of GBL in fostering student engagement and knowledge acquisition. Furthermore, this paper provides a valuable set of recommendations and strategies for educators and administrators interested in implementing GBL in higher education settings. It explores the potential benefits of GBL, including increased motivation, improved critical thinking skills, and enhanced problem-solving abilities. Additionally, it highlights the importance of aligning game design with specific learning objectives and ensuring the integration of assessment mechanisms to gauge student progress effectively. Moreover, this paper discusses potential pitfalls and challenges that may arise during the implementation of GBL in higher education. It addresses issues such as technology requirements, accessibility considerations, and the need for appropriate training and support for instructors. By acknowledging these challenges and offering potential solutions, this research aims to guide educators and administrators in overcoming obstacles and optimising the implementation of GBL in higher education courses.

Keywords: GBL, Higher Education, Engagement, Recommendations, Strategies

1. Introduction

Game-Based Learning (GBL) has gained significant attention in recent years as an effective educational approach to enhance student engagement and learning outcomes in higher education. In general, games, especially well-designed ones, focus on a type of learning that involves problem-solving and active participation (Gee, 2007). This approach encourages players to take an active role in finding solutions to the given problems. Complex games with challenging problems often necessitate the formation of support groups and specialised communities that offer assistance in finding specific solutions. Even experienced gamers usually rely on these communities to enhance their understanding of the game and improve their abilities to overcome the game's challenges (McGonigal, 2011). Research has shown that GBL can also promote valuable skills such as critical thinking, problem-solving, initiative, communication, and sometimes even subject-specific knowledge (De Freitas, 2018; Gee, 2013; Höyng, 2022; Marklund & Taylor, 2016; McGonigal, 2011). GBL can ignite learners' curiosity and inspire them to delve deeper into a subject beyond the traditional motivation of passing exams. James Paul Gee, in his essay "Good Video Games and Good Learning" (2007), elaborates on this concept and presents 16 principles that emphasise the elements of video games that can be harnessed for active, experiential, and problem-based learning. These principles include player interaction, challenging tasks and problems, player agency, and maintaining a flow that balances frustration and boredom, enticing players to continue playing.

In Higher Education (HE) settings, the ability of learners to engage actively in their own learning process is a desired and supported skill. GBL aligns with this objective and can also target cognitive skills such as critical reasoning, logical thinking, and independent knowledge building. Implementing GBL in HE also benefits educators and instructors. Having motivated and engaged students not only enhances the teaching and learning process but also fosters an environment conducive to experimentation and creativity (Pavaloiu et al., 2016; Xinogalos & Eleftheriadis, 2023). While GBL is typically discussed from the learner's perspective, for educators, having a motivated and engaged classroom that actively participates in discussions and contributes to the learning process is a valuable advantage.

One significant challenge faced by academics and lecturers in HE is the lack of adequate support to incorporate games as supplementary resources in their teaching. In personal interviews with academics regarding game-based learning, although they acknowledge its potential to enhance motivation and engagement, a common question arises: where do we begin? This question is often followed by inquiries such as selecting suitable games, integrating games into classes, and assessing student learning outcomes. These thought-provoking questions are addressed in the initial study discussed in this paper. The primary objective of this paper is to offer a set of guidelines and recommendations for academics and lecturers in HE who aspire to integrate game-based learning

into their teaching courses. The research question driving this paper is: What strategies should be employed to navigate challenges and avoid pitfalls when implementing GBL in higher education teaching and learning?

The remainder of this paper is organised as follows: it starts with a background section emphasising the significance of GBL in HE for both students and staff. It then proceeds with a literature review, exploring the principles and practices of designing effective game-based learning experiences. Subsequently, a detailed examination of a specific case study that attempts to integrate games into higher education learning practices is presented. This is followed by a discussion of key considerations, addressing the requirements of GBL, and outlining the challenges and pitfalls that should be avoided when designing for this form of learning. Finally, this paper concludes by providing a list of recommendations and strategies specifically tailored to academics and educators who are interested in adopting GBL at their institution. These insights aim to support the successful implementation of game-based learning and enrich teaching and learning experiences in higher education.

2. Background & Review of Literature

Games can be categorised as a form of media. Most often games are associated with and as a source of entertainment. Games are also very diverse in nature. Various genres of games appeal to a wide variety of audiences irrespective of gender, race, age or culture (De Freitas, 2018; De Freitas & Griffiths, 2008). There are games that possess great complexity, as well as games that are quite simple in their logic and game rules. The beauty of games in general lies in the ability to create an engaging environment that offers a balanced flow between boredom and frustration in an attempt to solve the game's quest (Gee, 2013). However there is a distinct difference between games that have been designed and created for entertainment purposes and those that have been specifically designed as media for training and learning. Researchers are also quite divided on the role of games for learning. Whereas some researchers present studies on the design of games that teach specific content, there are others who subscribe to the school of thought that view off-the-shelf games as the basis for the transfer of skills and competences to go beyond the acquisition of content information (Steinkuehler et al., 2012; Squire, 2011).

However when considering GBL, whether these are specifically designed or off-the-shelf, we must set aside our preconceptions and regard games as any other medium that contributes to the learning process. Just as we approach books, films, YouTube videos, Instagram reels, and academic papers as sources of knowledge, we can also explore games that have the potential to enhance, enrich, support, and stimulate learning, as well as instilling in learners a desire to learn more and in more depth.

Utilising a GBL approach in HE offers numerous advantages. Apart from employing a cutting-edge teaching method that enhances skills associated with modern literacies, a game-based approach primarily focuses on fostering critical thinking and problem-solving abilities through an active methodology framework. Research in GBL has been going on for decades and a number of results have shown that there have been a number of successful initiatives in higher education (Marklund & Taylor, 2016). A few recent publications explore the notion of using games as mediators to improve the perception of higher education students of the various subjects such as accounting (Sugahara & Cilloni, 2021), project management (Jääskä & Aaltonen, 2022) and others (Höyng, 2022; Stiller & Schworm, 2019; Xinogalos, & Eleftheriadis, 2023). Results from these studies indicate that whilst GBL may not be directly responsible for improved performances or perceptions related to the subject it may indeed be responsible for a deeper engagement with the content following an increased curiosity in getting to know more about the subject itself. However it has to be said that each GBL experience is quite unique in its application at the classroom level, and it is dependent on a number of variables. These include learners' attitudes towards games, the subject/skill that is targeted through the game, the environment/context in which games are played and the lecturers/teachers/academics' confidence in games and playing. Although in theory, GBL can be applied across a wide range of subjects and disciplines, at Higher Education level, where more depth in the skills and knowledge is expected, not all games can target the learners' and educators' needs equally. Specific subjects/fields of study may require specifically designed games to reach the scope of the content. The following is a summary of some of the benefits that using games in HE might offer to both learners and indirectly also to academics or educators.

1. Enhanced student engagement and motivation; research has indicated on numerous occasions that GBL leads to enhanced student engagement and motivation provided that the game which is made use of is tailored to the needs of the player at the time that is needed, in order to provide the player with some form of meaning in context (Sugahara & Cilloni, 2021). When a learner becomes engaged in the learning process it is expected that s/he would move beyond learning facts or information towards constructing knowledge that is needed for an improved performance.

2. Development of critical thinking and problem-solving skills; well-designed games often contain problems which the player needs to solve before advancing to a higher level (Tay et al., 2022). Problem solving requires lateral thinking and critical thinking skills which are considered as some of the more generic cognitive skills that are not directly subject content related. Research has also shown that these skills are important for the 21st century literacies that characterise technology driven societies (Squire, 2011).
3. Increased collaboration and social interaction; through multiplayer and online networks, players most often make use of communities having diverse skills, to hone in on their experiences, and help them overcome game challenges and solve problems to master their level of the game (McGonigal, 2011).
4. Personalised learning experiences; games offer personalised experiences of the learning process, depending on the level of ability of the player, as well as his/her scope in playing the game (Troussas et al., 2020). AI provides ways of adapting game difficulty based on the player's progress and performance. This means that the game difficulty level is adjusted gradually to enhance the player's experience rather than make it frustratingly difficult.

GBL for HE offers enough flexibility to educators and academics in the field, to include a diverse range of game genres, each offering possible unique educational benefits. Simulation games, such as medical or business simulations, allow students to apply theoretical knowledge to real-world scenarios. This also allows for a more empathic approach to skill building. Puzzle games promote critical thinking and problem-solving skills, while role-playing games encourage empathy, teamwork, and decision-making in complex situations. Strategy games foster strategic planning and resource management, while trivia and quiz games reinforce content retention. Adventure games can immerse learners in historical or cultural contexts, enhancing their understanding of the subject matter or the context in which the content is placed. Narrative-based games combine storytelling with interactive gameplay, enabling students to explore complex concepts within a compelling narrative framework. By immersing learners in rich, branching narratives, such as historical reenactments or futuristic scenarios, narrative-based games enhance critical thinking, decision-making, and problem-solving skills. Moreover, they promote emotional engagement and empathy, as students connect with characters and make choices that impact the story's outcome.

3. Case Study

In this case study, we examine the results of an exploratory study conducted by the University of Malta, which aimed to gain insights into GBL and its effectiveness in engaging language and linguistics students with academic topics. The study involved two surveys, with the first survey focusing on identifying student preferences regarding games in learning environments. Based on the findings, a narrative text-based game was chosen to be developed, aiming to engage participants in discovering more about the language-driven profession. Moreover the scope of such a game, included fostering skills that lead to critical thinking, decision-making and problem-solving. The second survey evaluated the game's impact on a select group of language and linguistics students.

3.1 Objective

The primary objective of this case study was to determine the effectiveness of a narrative text-based game in engaging language and linguistics students with the academic subject matter, and to assess whether such games could foster further interest and knowledge in the field.

3.2 Methodology

A first exploratory survey involved 215 respondents, and aimed to determine the needs and preferences of language and linguistics students regarding games in learning environments. The survey results indicated that while games might not be a top priority for all participants, those who enjoyed playing games preferred simple, short games with engaging narratives that could also facilitate learning.

Based on the findings from the first survey, a narrative text-based game was developed. The game's objective was to lead participants into a mission of discovering the language-driven profession, targeting students' interests in engaging narratives while incorporating educational elements.

A second specifically designed survey to gain insights into the perceived effectiveness of games in learning involved 25 language and linguistics students who voluntarily participated in the narrative-based text game. The survey aimed to gain insights into the game's impact on participants' interest in the subject matter and their perception of the game's effectiveness as a learning tool. Together with the survey, interviews with participants revealed further insights into the perception of the effectiveness of games for learning at higher education level. Results from the interviews were coded using thematic analysis.

The pre and post- game survey, together with the focus group interviews used a triangulation method of research that could provide the basis of the recommendations for the uptake of games at a higher education level.

3.3 Results:

The initial survey results suggested that language and linguistics students preferred games that were simple, short, and had an engaging narrative. They were more inclined towards games that could promote learning, rather than those that involved complexity or physical action.

In the Game Evaluation Survey, almost all participants (96%) expressed enjoyment in the narrative of the game. However, some participants (44%) expressed a desire for more complexity in the questions and missions. Despite this, 60% of respondents reported that the game made them think further about aspects of the language specialist profession. Furthermore, an equal proportion (60%) mentioned that playing the game motivated them to explore the subject in more depth.

The results of both surveys indicate that narrative text-based games can be effective in engaging language and linguistics students with academic topics. Although a subset of participants desired more complexity in the game mechanics, the majority reported increased interest and curiosity in the language-driven profession after playing the game.

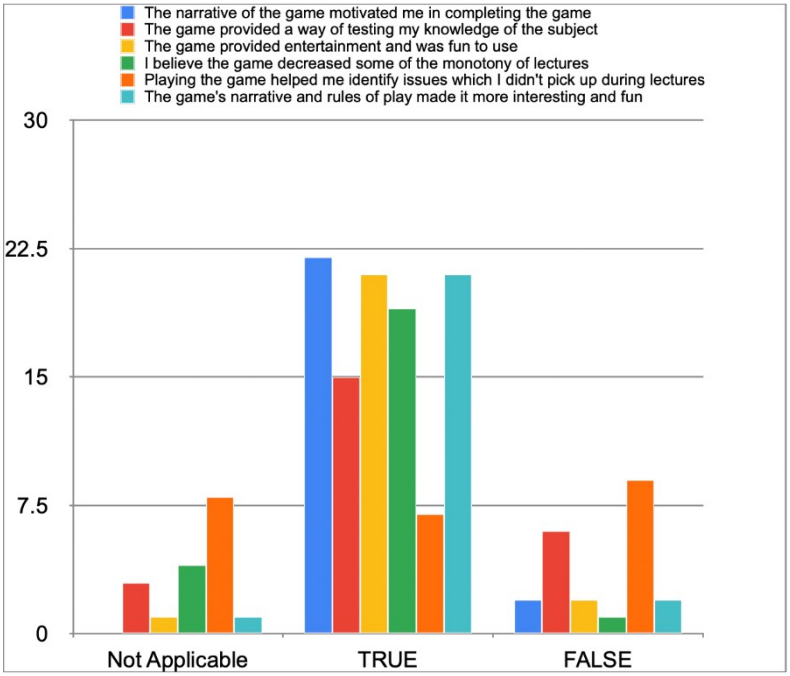

Figure 1: Frequency Distribution of the Participants' self reported game engagement (n=24)

The results from the surveys gave an indication that narrative text-based games have the potential to engage language and linguistics students and foster further interest in the subject matter. While some participants desired more complexity in the game, the majority still acknowledged the game's ability to inspire them to explore the language specialist profession in more depth.

In addition to the administered surveys, structured interviews were conducted among the study's participants, with the primary objective of soliciting comprehensive feedback pertaining to the integration of gamified elements in higher education pedagogy. All interview sessions were meticulously transcribed, and the ensuing qualitative analysis revealed the emergence of two overarching thematic categories. The first of these themes, denoted as "Theme 1: Game Play," exhibited a multifaceted spectrum of sub-themes. These sub-themes encompassed the classification of game genres, the exploration of competitive dynamics, the examination of conflict resolution strategies, and the nuanced dynamics surrounding collaborative teamwork within the context of educational gaming experiences. Meanwhile, "Theme 2: Assessment" served as the second salient thematic category, wherein participants deliberated extensively on matters encompassing skill identification processes and the assessment of academic achievements within the gamified learning environment.

The results from this case study highlight the value of well-designed narrative games as a complementary tool in academic settings, encouraging learners to engage with subject matter beyond the traditional classroom approach. Further research and refinement of such games could pave the way for more effective GBL experiences in the future.

4. Reflection & Discussion

The study underscores the importance of strategic planning and design when integrating game-driven pedagogy for successful teaching and learning experiences using games. The following are a list of reflection points arising from the literature and from the initial exploratory research in the case study.

1. Clear Learning Objectives: The development of a game should be guided by well-defined learning objectives. These objectives should align with the subject/skill being taught and facilitate specific, grounded learning outcomes. By brainstorming ideas related to the subject matter, educators can map out learning objectives that resonate with students' critical skills and content knowledge. This process ensures that the game's pedagogical design aligns with the desired educational outcomes.
2. Incorporating Relevant Curriculum Content: While games offer unique learning opportunities, not all subject curriculum needs to be addressed within the game. Identifying key aspects of the curriculum content, along with additional skills for deeper engagement, can enrich the gaming experience. By prioritising relevant content and skills, educators can map them into measurable objectives, enhancing the game's educational value.
3. Aligning Game Mechanics with Learning Outcomes: Game mechanics, including rules, challenges, and objectives, play a crucial role in shaping gameplay. To maximise the educational impact of a game, educators must ensure that the gameplay objectives align with the identified curriculum content and learning outcomes. While a perfect match may not always be possible, mapping gameplay objectives to relevant curriculum content can enhance the game's educational effectiveness.
4. Providing Meaningful Feedback and Assessment: One of the challenges in using games for educational purposes is evaluating students' learning progress. Incorporating various forms of feedback and in-game assessments can be highly effective in promoting continuous learning. This approach encourages students to improve their skills and knowledge by overcoming challenges within the game. Additionally, alternative assessment methods, such as engaging students in discussions and open-ended questions, foster reflective learning and critical thinking throughout the GBL experience.

4.1 Challenges & Pitfalls:

GBL is not without its challenges and pitfalls. A number of academics and educators often express difficulty and reticence to integrating games into higher education learning. Most often such reticence may be associated to resistance to change, however at times this is also reflected to limitations of technology infrastructure and resources available as well as lack of knowledge of games and gaming. The following is a list that emerges from the case study above and which includes a number of challenges which academics and educators describe as potentially limiting to taking up GBL at higher education level.

1. Time and Resource Constraints: Managing time and accessing sufficient game resources can be challenging. To overcome this, faculty should allocate support staff to educators and academics involved in GBL. These experts can ensure access to necessary infrastructure, pedagogical materials, curriculum integration, and assessment strategies, facilitating successful implementation.
2. Assessment and Grading in GBL: Traditional assessment methods may not align with GBL's experiential nature. Utilising in-game outcomes, such as scores and experience points, provides valuable feedback and encourages reflective discussions on learning outcomes within the study unit.
3. Overcoming Resistance to Change: Introducing innovative pedagogical practices like GBL may face resistance from the teaching and learning community. Overcoming this resistance involves taking small, guided steps, showcasing successful GBL examples, and offering support and training to educators through faculty support staff and pedagogical experts.
4. Ethical Considerations and Student Well-being: Designing, creating, or using games for learning requires careful consideration of ethical aspects. Key considerations include obtaining informed consent, ensuring accessibility and inclusivity, protecting student data, promoting fairness and psychological well-being, respecting intellectual property and copyright, and emphasising ethical game design and academic integrity. Adhering to these principles ensures a positive and inclusive GBL environment for students.

5. Recommendations & Strategies:

The proposed strategies aim to contribute to the existing body of knowledge in GBL and suggest potential areas for the future development of innovative pedagogies in higher education.

1. Institutional Support and Policy Development:

- Full institutional support is crucial for successful GBL implementation in higher education.
- Dedicate pedagogical support staff to assist academics in selecting appropriate games, ensuring technological infrastructure, and promoting ethical practices.
- Collaborate with game designers, academic experts, and technologists to develop games that align with teaching and learning objectives.

2. Collaboration between Faculty and Game Developers:

- In-house game development requires interdisciplinary collaboration to enhance user experience through AI, psychology, sociology, and game design.
- Involve industry partners when institutions lack game development centres to provide technical expertise and aesthetic design.

3. Continuous Evaluation and Improvement:

- GBL should be viewed as a dynamic educational resource adaptable to various contexts and purposes.
- Employ diverse assessment procedures to gather qualitative feedback, leading to enhanced game mechanics and an improved learning environment.

4. Sustainability and Scalability:

- Consider the long-term sustainability of GBL resources, accounting for staff time, development costs, and maintenance.
- Implement management plans to address server maintenance, continuous feedback, updated guidelines, and ethical academic use of games.
- Explore acceptance and adoption models to build confidence in using games across different fields of study and settings.

6. Conclusion

In conclusion, this paper aims to propagate the notion of the significance of GBL in HE, presenting valuable recommendations and strategies for a successful implementation. Institutional support, interdisciplinary collaboration, and continuous evaluation play a crucial role in enhancing GBL's impact on student engagement. These practical recommendations can be used to foster an innovative and dynamic learning environment that empowers both educators and students to thrive in the digital age. More research insights are needed to create sustainable, inclusive, and immersive learning experiences that will shape the future of education. As GBL continues to evolve, further research and refinement of game-based approaches hold promise for enhancing learner engagement and academic success.

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Experimenting with GAME OVER to Create Processes of Reflection and Academic Inquiry

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Abstract: Educations are challenged in their effort to facilitate students learning when it comes to especially processes of reflection. Also in a Problem-Based Learning context, errors often cause a lack of motivation, that gives reflection processes and academic inquiry difficult conditions Game-Based Learning is thus suggested as a learning strategy which can address these learning needs though a procedural rhetoric. Furthermore, Game-Based Learning is found to affords students risk taking and engagement in learning activities However, a literature review of empirical studies of Game-Based Learning reveals existing gaps in the literature. There are missing models for how academic activities can be enhanced through the use of Game-Based Learning, here especially the transformation of "Game Over" elements into a learning environment based on physical Game objects. This study aims to describe learning situations where the academic focal point is a reflective and innovative writing process through gaming principles. The study design aims to identify what impact Game-Based Learning have on facilitating academic literacy to create processes of reflection. Based on two cases, the empirical data are retrieved from video observations during a period of 1 year. A qualitative content analysis and interpretation of the collected data reveals how the use of "Game Over" strengthens the depth of the students' writing through a reflective and metacognitive approach to the task. As a contribution to the existing knowledge, this paper presents a Procedural Rhetoric for how to work with a "Game Over" strategy to facilitate academic literacy and thereby create processes of reflection in a physical context.

Keywords: Game Over, Fun Failure, Reflection, Procedural rhetoric, 21st. Century Skills

1. Introduction.

In recent years, the concept of knowledge is changing. Knowledge is no longer perceived as a static entity; instead, it is continually shaped and reshaped through analytical and reflective processes (Adams B. et al., 2017; McConville et al., 2017; Rodrigues and Bidarra, 2017; OECD, 2019). OECD (2019) highlights the significance of two overarching trends: the "Increase of complexity" and the "Speed of change." These trends necessitate the ongoing evolution of educational institutions to equip students with the essential 21st. Century skills and competencies required for a modern world (OECD, 2019; Rahim et. Al., 2019). Evidently, educational institutions are increasingly focusing on developing innovative and active forms of learning that empower students to actively engage with knowledge and new ideas. This approach positions students as partners in their own learning trajectory, fostering active knowledge creation (Adams B. et al., 2017; Becker et al., 2018). OECD (2019) emphasizes that the future does not merely entail a continuation of past educational patterns. Accordingly, there is a growing advocacy for a departure from traditional lecture-based teaching methods, which primarily involve the transmission of knowledge, towards emerging educational concepts such as Authentic Learning, Project-Based Learning, Challenge-Based Learning, Competency-Based Learning, Inquiry-Based Learning, and more (Adams B. et al., 2017; Paaskesen and Nørgård, 2017; Becker et al., 2018; OECD, 2019). Paaskesen and Nørgård (2017) take this perspective a step further by arguing that merely participating in projects aimed at producing creative and innovative outcomes is insufficient. They advocate for an education framework rooted in open exploratory and experimental learning designs within open learning environments. This approach emphasizes open learning cycles that strike a balance between what they term "directed" and "emergent learning," with key concepts including creation, imagination, play, sharing, and reflection (Paaskesen and Nørgård, 2017). Nevertheless, ushering in a new educational paradigm presents a multifaceted challenge, requiring learning models built upon complex design criteria (McConville et al., 2017).

Based on experimental participatory design this article presents a case study at the education of architectural and construction management education at UCN. The educational philosophy of UCN centers on fostering a dynamic interplay between theory and practical application. In this approach, students are actively engaged in learning, requiring them to analyze, solve problems, develop solutions, communicate effectively, explore various facets, and engage in investigative processes—all underpinned by reflective thinking that point towards the development of 21st. Century Skills (Rahim et. Al., 2019). However, students enrolled in technology programs at UCN often lack well-defined learning strategies for delving deeply into the curriculum through an explorative and analytical approach. They frequently find themselves in situations where they are uncertain about the next

steps and therefore may not fully grasp the value of working reflective with the ability to question and adapt to the demands of their professional context. (www.ucn.dk, 2020).

In the following, a general description of the Game-Based Learning and the concept of Procedural Rhetoric is elaborated. Then the article presents a case study based on a specific Game-design. This is follows up by a description of how data is collected and analysed. Based on the analysis, the article ends with a final debating conclusion where we sum up the main findings from the study and offers a methodology for how to work with Game-Based Learning without having to apply existing computer Games that do not meet the substantive requirements of the instruction and the learning situation.

2. Theoretical framework.

Game-Based Learning has gained increased attention within higher education with the aim of inspiring new learning designs that challenge students' ability to explore different academic perspectives and experiences through active and reflective dialogues. However, for Game-Based Learning to realize its potential, it is crucial that the Game is well-designed (de la Hera et. al, 2021; Gurbuz, & Celik, 2022). This entails developing Game design techniques that promote in-depth learning, connecting theory and practice through reflection processes, rather than merely short-term motivation. In practice, it can be challenging to reconcile Games with pedagogical principles in a meaningful way, where both the academic content and the pedagogical visions are integrated into the core Game activities (Squire, 2006; Ravyse et al., 2017; Patti, 2022). If a learning Game is not based on an integrated learning experience, there can be an overemphasis on "playing the Game" instead of learning through the Game (Egenfeldt-Nielsen, Smith, & Tosca, 2013; Ravyse et al., 2017). According to Egenfeldt-Nielsen, Smith, and Tosca (2013), educational Games are often developed with a focus on "drill-and-practice thinking" rather than understanding. This type of Game only encourages students to memorize answers and does not facilitate learning through exploration and experiential learning (Egenfeldt-Nielsen, Smith, & Tosca, 2013; Laine, & Lindberg, 2020). One of the reasons for this is that many educational Games are characterized by uninspiring narratives combined with an uninteresting Game structure that fails to sufficiently motivate and engage students in their own learning activities and experiences with an inductive approach. Recent litterature shows significant criticism and concern that a large portion of Games developed for educational purposes do not adequately support reflective, exploratory, and innovative learning activities (Qian & Clark, 2016; Krath et.al, 202; Laine, & Lindberg, 2020).

2.1 Procedural rhetoric.

Ian Bogost introduced the concept of procedural rhetoric, which provides a relatively new framework for the design of educational Games (Patti, 2022; Bogost, 2008) in achieving a holistic interaction between pedagogical principles and Game theory in practice. When playing to learn, the interplay of multiple consecutive decisions creates complex social, educational, and academic processes that impact future learning activities in various ways. Some decisions may seem immediately logical to the student, while others may be disruptive as they challenge the student's existing understanding. This is particularly relevant to theoretical understandings of learning in higher education, such as Reflective practice-based learning (RPL) (Horn et al. 2020; 2021) or problem-based learning (PBL), as it involves an approach to learning that connects theory and practice through reflection processes. The word "procedure" has historically had a negative connotation in pedagogy, as it has often been understood as something predetermined through deductive thinking (Bogost, 2021). Bogost challenges this notion and points out that it is a misconception that "rules always restrict behavior." We do things, we do them according to a certain logic, and this logic constitutes a process in the general sense of the word. It is this logic that can be explored, changed, or discussed through reflection processes, challenging the student's normative understandings. Only when normative and practice-related processes become clear in their logic is it possible to create a descriptive language that can support reflection. When using Game-Based Learning in higher education its thus important to ensure that the Game support academic activities and processes of inquiry (Doucet & Srinivasan, 2010; Bogost, 2008; Bogost, 2021). Academic inquiry entails a systematic and critical exploration aimed at acquiring new knowledge, fostering academic rigor, and attaining a comprehensive understanding of a specific subject matter. It holds a pivotal role within the realm of academia, urging students to pose questions, engage in critical thinking, and bridge the gap between theory and practice. This endeavour encompasses a combination of theoretical learning and practical application. Academic practice, on the other hand, pertains to the methods, techniques, and processes employed to pursue academic objectives and advance knowledge within a specific field or discipline. Within the context of academic inquiry, students employ theoretical frameworks to gather information, synthesize ideas, and generate fresh insights that address real-world situations (Gyldendahl, 2020; Horn et al. 2020; 2021; Dewey, 1998; Dewey, 2013). According to Schön (1968, 1987), inquiry in professional practice involves an ongoing process of reflection and learning, where

practitioners continuously evaluate their experiences to identify their own assumptions, biases, and limitations. They then utilize this self-awareness to enhance their practice. Schön underscores the significance of integrating reflective practice into the inquiry process, as it fosters profound learning and comprehension in professional contexts (Schön, 1968, 1987; Watts, 2019). Dewey's conceptualization of inquiry is understood as a process of reflection. The inquiry is an emotional experience where a conflict is embedded. The conflict acts as a trigger for the inquiry process when the situation is experienced difficult or uncertain. Prior experiences are activated to create meaning and action in the present learning situation. The process affords a cognitive transformation of emotional experience through thinking and action. Thereby, reflection occurs and become a learning experience and embedded knowledge. The loops of connected experiences are organically interrelated circles with individually unique characteristic (Dewey, 1998; Dewey, 2013; Buch & Elkjær, 2015; Buch, 2021). Procedural Rhetoric thus challenges the classical understanding of Game-Based Learning , where the focus is often on aspects such as the Game's narrative for conveying the academic content or Gameplay centred around winning and completion. Instead, it promotes a Game thinking that emphasizes establishing dialogues focused on exploring an academic subject while allowing students to perceive the relationships between specific procedural activities through a critical approach (Bogost, 2008; Bogost, 2021).

3. Research question.

This study is aimed at problem-oriented learning situations where the academic focal point is gamifying a reflective and innovative writing process. The study design aims to identify what impact Game based learning have on facilitating Students through a reflective and collaborative writing process.

The research question driving this study is: *How can Game based learning afford reflective practice among undergraduates through the use of a "Game Over" strategy?*

In the following section, the criteria of the study design will be described according to the theory of experimental and participatory case study. A description of the design setup and its content will follow afterward.

4. Methodology.

Based on experimental participatory design this case study relies on two classes in architectural and construction management education in their fifth semester. The selection of the case is information-oriented. It is a paradigmatic case selection aiming at establishing an example and school for the domain (Flyvbjerg, 2004, p. 426) of "Game Over" in a non-virtual context. The case study is chosen it allows to reveal events with little control and phenomena within holistic and real-life events (Yin, 2013). Case studies offer a way to capture social processes and development (Launsø, Rieber & Olsen, 2011). Thus, case studies are a design that has the possibility to map a complex situation where people and artifact interact. Case studies are accordingly suitable for looking into the affordance of fun-failure in gamification. Moreover, case studies allow for the different type of data collection and thereby methodological triangulation. However, not all data might be recorded in writing, but are selected by a professional judgment of the available data resources (Stake, 1995, s.49-50). The case story forms the empirical data and creates a history including a pivot point (Fog, 1994, s. 175). The pivot point is the plot (here main categories) created by the analysis though the structure of the content.

4.1 The Game design.

The case setup deals with the process of students' developing concept that aims to identify relevant problems within their field of professions. The task is structured through gamification principles where particular "Game Over" mechanisms are the focal point. The task is divided into five levels which together form a continuous learning process, while each level has its characteristics; what Dewey referred to as organic circles. The content is built around a sequence of headlines - words - sentences - paragraphs - full text. Along the way, students must follow some rules that support a gamification thinking. It is vital that the students voluntarily accept the selected rules. The first rule is about each level must be completed within a given timeframe. If time runs out, it's "Game Over" and everything produced is being discarded. If the student manages to solve the task within the prescribed time, they can save their work. Work being saved cannot be lost again. .

Level number	Sequences	Description
Level 0	1. attempts - 2.5 minutes 2. attempts - 3,5 minutes 3. attempts - 5 minutes	Through group work, the students brainstorm 24 titles in total to get to Level 1
Level 1	1. attempts - 5 minutes 2. attempts - 10 minutes 3. attempts - 15 minutes	Through group work, the students brainstorm 100 bricks of words in total based on the 24 headlines to get to level 2
Level 2	1. attempts - 10 minutes 2. attempts - 20 minutes 3. attempts - 30 minutes	Through group work, the students are going to use the headlines and bricks of words to create ideas for the project - 50 unique ideas in total. Every idea must be described in a sentence consisting of at least 5 words to get to level 3
Level 3	1. attempts - 30 minutes 2. attempts - 40 minutes 3. attempts - 50 minutes	Through group work, the students are going to merge their ideas into a variety of paragraph consisting of at least 3 ideas per paragraph. Each paragraph is described through text with at least 100 words per paragraph. There must be described at least 5 paragraph to get to level 4
Level 4	60 minutes	Through group work, the students are going to create a coherent text in which they apply at least 3 of their paragraphs. The goal is to develop a concept consisting of at least 1000 words to get to level 5
Level 5	Finished	

Figure 01: The table illustrates a summary of study contents and a set of requirements.

With each failed trial the specified time will be extended, and thus it is getting easier and easier for the student´s to succeed. Once the timer has started, it is not possible to pause; they can't stop the clock. The students can take a break between each trial and decide for themselves when they are ready to start again. The last requirement demands that all written material must be readable and understandable. Furthermore, sentences and texts must be coherent and profession relevant. In the table below (figure 1), each level illustrates the time sequence and the content including requirements. In the next section, a content analysis is presented as a methodology for processing of data. Thereafter, a description of the ethical considerations, applied in this study, is addressed. The ethical consideration is followed by the revealing of the data collection and the coding according to the procedure of the Content analysis.

4.2 Ethics

The study includes ethical considerations regarding the student's information about the nature of the project, and the rules of the General Law for the Protection of Personal Data were guaranteed. The conduction of the study is based on the student's voluntary participation, and they are thus familiar with the experimental and unpredictability character of the setup and the research process. Before the study has been carried out, the students have given a consent allowing the documentation of the process beeing carried out. The students have agreed that documented data from videos, sound, and writing can be used for publication and dissemination. However, data are anonymized according to the code of conduct. The data processing is not confirmed by the students.

4.3 Content analysis

The data analysis is informed by the process of qualitative content analysis. The content analysis offers a structure to the analysis of communication where the content and the contextual meaning of the text is framed from different sources of data (Lindkvist, 1981). In this case, data were retrieved from workshop observations, video and sound recordings and student´s written portfolio aiming for a methodological triangulation. The purpose of using content analysis is to gain knowledge and understanding of the phenomenon under study (Downe-Wamboldt, 1992, p. 314) and in our case the specific phenomenon of gamification. In this paper, a directed approach has been applied. Hsieh & Shannon (2005) distinguishes between three different approaches to content analysis; a conventional, a directed and a summative approach. As this analysis is framed by both theory and concepts creating the phenomenon a directed approach to content is taken into use with the purpose to extend the existing conceptually theoretical framework of gamification methods. In the directed approach to content analysis; “Fun-failure,” “Sequential Constructive Learning,” reflection, metacognition, literacy, and engagement has been used as key concepts in the initial coding and in the coding of interrelatedness as suggested by (Potter & Levine-Donnerstein, 1999). These codes are defined before and during the data analysis and derives from theory and relevant research findings.

14 students from 1 class and 14 students for another class. The selection has taken into account the students metacognitive thinking and their ability to engage in participatory designs. The data collection consisted of two eight hours workshops in each class monitored by three cameras. The empirical data were retrieved from 48-hour video observations (Heath et.al. 2010; Mortensen & Hazel, 2012), 48-hours audio recording, and the students' written 8 group portfolios. The data has been collected during intense workshop being held over a period of one year.

An Annotating of visual cues or events in the retrieved data from the video-recording were conducted. Annotating visual cues or events in video data involves identifying and labeling specific moments, objects, actions, or other visual elements within the video. This process is crucial for extracting meaningful information from video recordings, and thus what makes it possible to see how the students acted when playing the Game by following their patterns of movement and body languages (Heath et.al. 2010; Mortensen & Hazel, 2012). The Audio recordings were transcribed (Kvale, 2014) and coded according to the guidelines of the content analysis. The transcription of the audio recording was coded up against the video annotating and the written materials from the portfolios.

Figure 02 illustrates the finding form the content analysis based on the different steps of analysis. The categorization reveals how structure, motivation, progression embodiment, forethoughts, collaborative commitment and a writing flow affords the students learning the process. Accordingly, the identification of meaning arise. In the next section, the six chosen key concepts will be further explained based on the result of the coding process and analysis thereof.

Key concepts	ACADEMIC INQUIRY	FUN-FAILURE	SEQUENCED CONSTRUCTIVE LEARNING	REFLECTION	ENGAGEMENT	LITERACY
A coding	Exercise, Strategic, Thinking * Plan * Understand, Think, what, How, why, Which, Consider *	Yeah, Yes, Level, Finish, Oh, Swearing, Bad * Good *, Slow	Time, Level, Exercise, New, Level up	Think*, wait a moment...	Plenum	Portfolio, Process
A description of behavior	"The students' organization and structuring of the physical material."	"The face expresses disappointment." "The hand is tied and lifted."	"The students are preoccupied with times."	"The glance is raised by a staring expression." "The face is hidden in the hands."	"Collaborative behavior." "Individual workflow."	"The students build on prior experience; words become sentences, sentences become pieces of coherent text
A mapping of interrelated concepts	Dewey's understanding of breaks and mechanical stop - related to reflection	Engagement and sequential structured learning	Engagement and literacy	Dewey's understanding of inquiry related to fun failure and metacognition	The concept of affordance related to fun failure	Metacognition and sequential constructive learning
Grouping and categorization	Structure, systematics, overview, strategy	Motivation, Fiero Expression, Self-efficacy, Behavioral persistence	Progression and Frameworks	Thoughtfulness, Embodiment	Collaboration and Commitment	Writing flow
An identification of meaning	Pre- and after processing of learning	Inner drive and external scaffolding (actual affordance)	ZPD and structured experience (Actual affordance)	Mental and embodied Knowledge creation and experience	Peer-learning (Perceived affordance)	Academic Outcome (Reel affordance)

Figure 02: The table shows the concepts, descriptions and words that have formed the data processing.

5. Analysis

The findings are based on qualitative content analysis and data interpretation. Based on coding the retrieved analysis categories of interpretation were; metacognition, reflection, literacy, "Fun-failure," "Sequential Constructive Learning" and engagement. Those categories include both the emotional, the cognitive and the mechanic phenomenon of gamification.

5.1 Academic inquiry though a procedural rhetoric

Academic inquiry though aa Procedural Rhetoric is found to involve student's behavior within in strategic planning of the task in their effort to achieve the goal. The student is before each round, very conscious of the need of having a strategy for how to address the task. The systematic and the structure of the assignment affords the progression. The example below illustrates how the students create an analogy to video Games regarding what it takes to win. Thus they bring the basic principles of winning a computer Game into their assignments - it's not just about the doing the assignment but just as much to defeat yourselves. Moreover, the motivation and experiences retrieved from prior gaming become perceived affordance in the process. Affordance is thus

botted independent of the dispositions or the use of objects associated with the embodied tacit knowledge and nested routines.

Person 2: It a good idea to use these extra minute because otherwise, you could easily risking starting all over again

Person 1: you prepare through a strategy before starting

Person 2: and then you go to war

Person 2: Then you just shoot the enemy

Person 3: we are making a strategy

Person 2: strategy for (swearing)

Person 2: This is what it is all about

Thus, the motivation to win, indirectly, pushes the students towards working on a metacognitive level trough a reflexive discussion of how to solve the task. For instance by questioning: How many ways can it be done? And what methods are the most appropriate according to create useful knowledge? The next example shows the student's awareness of how idea generation is supporting and making sense regarding professional approached to the content of their project.

Person 2: No, but it just does not make much sense, you can say

Person 3: For what should we use the word scissors?

Person 3: It should be something about crafting building

The students' discussions illustrate that they, in their strategic planning of the idea-generating, is trying to establish some rules to ensure a professional approach to their brainstorm process - the outcome should make sense regarding the breadth and complexity of their projects. For example, a question about whether words covering building materials are too narrow, regarding the professional context, are discussed. These Academic discussions are essential for maintaining a professional quality of their work, and thereby they are not tempted to finish and to hasten the final goal.

Person 2: But, is there someone who can focus on anything inside the building and then someone can focus on anything around the outdoor areas and then there is somebody focusing…

Person 1: What if someone is concentrating on materials

Person 2: But is it not, don't you think that would almost be too narrow?

Person 1: Materials in general, I am (swearing) you can find around 40

Delegation is a central part of the collaboration aiming at solving the task. Academic inquiry is found not only in advance of each assignment but also visible afterward. Thereby both pre- and post-processing are present in the quotes revealed. Situations where students fail to solve the task within the stipulated time sequence and thereby experience "Game Over," can be observed several times. Here, they reflect on a metacognitive level, regarding the factors that had an impact on why they did not reach the goal. The example below shows how a student verbalizes his own idea generation process by using the term ”dead." Based on this experience, he requests the other group members of help regarding how to shape up in the next attempt.

Person 2: Well I need to have an art break, could you just try to make a plenum about what I can write about?

Person 3: Yeah, because I also went down all the sudden, and then ten more came, and the five more

Person 2: I came to write the sun, yes, spring, summer, winter, snow, and then I went dead again

The analysis thus reveals that the use of gamification forces what Dewey call breaks or recovery periods. It creates moments where the students have the opportunity to define the quality or the direction of their work. The students use the pauses between each round to make the status of their progressing and summing up. Academic inquiry is also a part of literacy competence develop through the process. For instance, Academic inquiry is afforded by the combination of the embodied activities and the written mediums visibility. The data´s video material thus illustrates how the strategic planning of the task is clarified through a sorting and structuring

of the written media. The students' literacy skills are linked to a bodily dimension through the physical material which can be combined and moved around on the table.

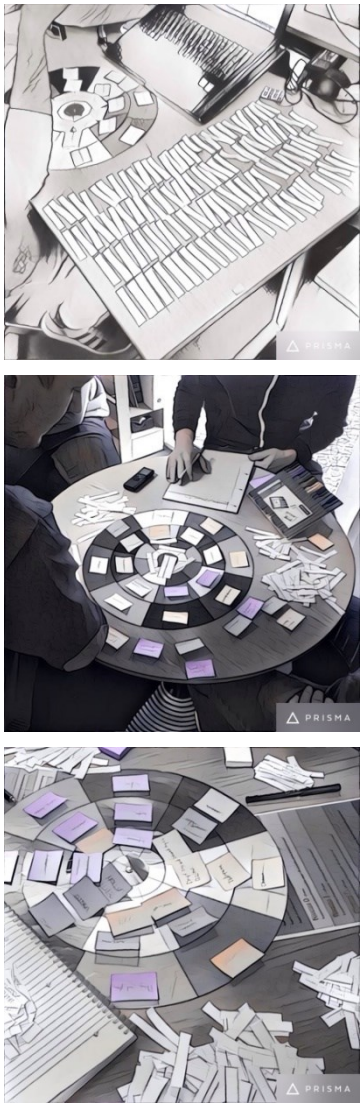

Figure 03: Scraps of paper expressing respectively headlines, words, and phrases

Through the small scraps of paper expressing respectively headlines, words, and phrases, the students can work and organize specific disciplines through various thematisations (figure 03). The academic discussion thus supported the students' ability to see connections or combinations between the written headlines and words. The selection of these acts as stimuli to help the formation of new and alternative suggestions or problems which may be subsequently incorporated into the project. The “hands on” material raise an embodied awareness of the combined process of metacognition and literacy skills (figure 03).The use of Game-Based Learning through a "Game Over" mindset regarding the structuring of the task, supports an open idea generating process as the students did not have "time" to stop up and reject the crazy ideas. This open approach releases ideas and words that otherwise would have been sorted out through dialogue if the working process had not been forced by Game-Based Learning . A large part of the combinations, will due to the ”Game Over” mindset not form ideas that make sense in the first place. A conversational reflection is, therefore, necessary since it includes questions such as "that is very strange," "how are we to understand it?" "what can we get out of this combination?" etc. These crazy ideas thus create a provocation, which aims to force a reflection about the relevance and how it appears relevant. The many examples above seems to support the findings of how the student´s through intense conversation created by the "Game Over" principle obtains a academic perspective on their ideas based on a procedural rethoric.

5.2 Reflection

In the beginning, reflection seems to be superficial or tacit by the reflection in action, but at the end, reflection is visible in their creation of the written portfolio, where the reflection reveals both cognition and the solving of the prior conflicts gained by the process of inquiry. The physical artifact acts as a trigger of abstraction, obstruction, and lateral thinking. The reflection is visible in the situations where the students are speaking loudly about being under pressure due to running out of time. Phrases like; *"I'll just go lock myself into my mind"* or *"What is it? It says architecture, now we think, we think - green lines"* illustrates how the reflection become the grip, which creates a necessary concentrated and focused process. The "Game Over" principle thus provokes to an immediate and direct reflection. Moreover, reflection is furnished in embodied interactions. The analysis point towards that the "Game Over" principle compels what Dewey describes as an emotional meeting in an experience with an embedded conflict. The students are affected emotionally by the desire to win, and at the same time, they want to maintain a professional quality. Dewey points out that it is precisely in situations where there is a feeling about something being difficult that inquiry is the method to resolve this conflict and afford meaning. Video material reveals repeated examples of how the students through their body language use inquiry as a tool to maintain the idea generation process. The illustrations below pictures how the students are "hiding" their faces in their hands to create a maximum concentration. Another example is situations where the students look up from the table with a fixed look out in the room, to maintain their thoughts (figure 05).

Figure 05: Reflection present in embodied actions

The non-verbal actions illustrated in figure 05 are part of the emotional expressions in the reflective processes. Those processes are interrelated to the emotional experience in the situation. The complexity of bodily expressions raises forethought and pictures the embodied engagement. The reflections and forethoughts afford a foundation for the upcoming literacy process.

5.3 Literacy

According to the category of Literacy, the findings from the portfolio reveal how the use of gamification affords the quality of the students' writing through a reflective and collaborative approach to the task. A step by step approach facilitates the writing process in a continuous flow. Dewey is, for example, talking about “series of continuous situations” or the “organic circles” which can create learning through inquiry. These situations of reflection are all linked with each other while each of them possesses unique characteristics. The case set up where students through five phases are preparing a concept for their project can be characterized as a series of contiguous situations. It is precisely the students' reflections wich becomes the factor that creates a movement from words into a coherent text. The following example illustrates a discussion of how the random word "concrete" ends up in the idea *"Concrete floors in the kitchens to create an industrial look."*

Person A: *Should we take concrete?*

Person B: *Can we make the concrete floor in the kitchen?*

Person A: *That could be cool*

Person B: *It could give a cool…*

Person A: *…architectual, yes*

Person B: *Yeah but, yes as an industrial, what's the name?*

Person A: *Yes, exactly*

Person B: an industrial look

Person A: Concrete floor in the kitchen to…

Person B: to get an industrial look. That way it could also be.. but there is also sustainable, you do have a long lifetime for it

A review of the group's subsequent work shows that the idea was incorporated as an integrated part of the conceptual thoughts. The initial and superficial reflections are thus visible later in the writing process. The specific analysis reveals that the structural use of gamification as a series of coherent levels ensure that student's quality in work in all planned phases as no stage can be skipped, which is also not questioned by the students. The early reflections help and support the students' writing process by building on previous experiences in a movement from words to phrases and to coherent text.

5.4 "Fun Failure".

The category of "Fun Failure" is closely connected to the sequential constructive learning process. The analysis reveals that the principle "Fun failure" and engagement is expressed in both verbal and nonverbal attitudes. A "Fiero" behavior is expressed as an emotional benefit of hard work as a result of the "Game Over" strategy.

The examples below in figure 07 pictures how the hand is tied to a fist when a winning experience occurs. If, however, the experience is "Game Over" a disappointed facial expression is revealing irritation of the planned strategy not beeing sufficient. The last types of examples are situations where the students are hiding their faces in their hands to ensure maximum concentration.

Figure 07: The student's body language, reveals the phenomenon of "fun Failure" by expressing a "Fiero" behavior

Besides the bodily expression, the presence of "Fun Failure is illustrated in the students´ conversations. In the following quote "come on, last one last one, it's the last one we need now" the student is clearly expressing a desire to win and tries through pep talk to encourage his team members to intensify their efforts and behavioral persistence. The inner drive is pictured in the bodily behavior and the emotional outbursts expressed by; yeah!, Good!, Oh!, Bad!, Yes! and swearing. The students desire to win affords an engagement in the approach and alternative thinking to accomplish the task and thus an actual affordance in relation to self-efficacy. Thereby, the "Fun Failure" supports the inner drive through the external scaffolding.

6. Discussion and conclusion

As a contribution to the existing knowledge, this current understanding, and the case study adds new perspectives to the pro and cons of Game-Based Learning. The case study offered in this research has raised out of the desire to understand the complex phenomena of Game-Based Learning though the use of a Procedural Rhetoric to create a reflective and collaborative practice by using two specific gaming principles; "Fun Failure" and "Game Over." The case study provides a way of investigating a phenomenon within blurred contexts where there are several variables of interest and multiple sources of data. The educational Game-Based Learning design in this study reveals how a "level thinking" and "Game Over" strategy creates the phenomenon "Fiero" behavior. "Fiero" behavior is regarded as an emotional benefit of hard work. Even through "Fiero" behavior is a term used by the Game industry it is measurable within learning environments. This emotional behavior is an expression of the gaming principle "Fun-Failure". Thus, "Fun failure" creates the possibility to engage students. Accordingly, this paper adds new perspectives to the measurement of learning within "fun failure" environment. This is illustrated in the findings of "Game Over" and "Fun Failure" as triggers for reflection and metacognition observed by video and sounds. By thinking in a simple and direct application of gaming principles, it is possible to design a learning situation that can facilitate academic inquiry and literacy through a reflective and collaborative

approach. Therefore, this study offers a methodology for how to work with Game-Based Learning without having to apply existing computer Games that do not meet the substantive requirements of the instruction and the learning situation. The real and percieved affordance of Game-Based Learning are also revealed in the assessment of group work, where student's individual contributions are comparable to peers in a situation where gamification is applied. Finally, this study illustrates how to work with Game-Based Learning aspects without using technology and traditional learning managements system (LMS), by applying gaming principles to a physical non-virtual context. This approach contributes to existing research within the field of Game-Based Learning as it offers a model of Game designs element in non-Game contexts. To afford academic inquiry and deep reflection rules are essential. You can´t play a Game, for instance, soccer, without knowing the rules and the actions of the Game. In contrary, if the Game is without rules chaos and regression might be the result. When Games and learning are coupled by rules, it provokes reflection and affords knowledge creation. Game-Based Learning is not about learning the curriculum but changing the learning conditions. However, you need all the "puzzle pieces to create a puzzle picture."

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The Application of Games to Engage Citizens in Climate Change Policy Development

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Abstract: This paper introduces the Games Realising Effective and Affective Transformation (GREAT) research and Innovation project. The project will examine the emerging ways Applied Games could be used to facilitate the social engagement of European citizens in determining future policy priorities and policy interventions to the existential challenge of climate change. This full paper is a provides detail of the work in progress but moreover provides a a conceptual analysis of the methodologies applied to this emerging domain of study. The project is funded by the EU Horizon programme with UK Associate partners funded through UKRI and coordinated by the DIPF, Leibniz Institute for Research and Information in Education, Frankfurt and involves seven partners located across Europe, Serious Games Interactive (SGI) Denmark, Centre for Social Innovation (ZSI) Austria, International University of Rioja (UNIR) Spain, Frederick University, Cyprus, Playmob and The University of Bolton (UoB) as UK associate partners. The project incorporates collaborative design and citizen science methods and brings together researchers with expertise in the areas of games, data analytics, and policy development. This integrated investigation will be articulated by case studies of the use of games in facilitating dialogue between citizens and policy stakeholders including policy makers, policy implementers, political parties, campaigning organisations and affected citizens. This will be achieved by leveraging the central role of games in contemporary culture by combining academic studies with practical experimentation of novel applications of games. The context for the research is the global challenge of climate emergency, and each case study incorporates a research cycle addressing a policy issue and research questions, using multiple pilots to generate both quantitative and qualitative and data to further inform research activity.

keywords: Applied games, Climate, Learning, Analytics, Policy

1. Introduction

The GREAT project involves partners across Europe and aims to enhance citizens dialogue with governments and policy agendas relating to actions to mitigate climate emergency, using applied games to facilitate this by specifically addressing the development techniques deployed to engage players and how these could be meaningfully applied to wider societal challenges.

It is well established and documented that the digital games industry in financial terms is a larger economic sector than either of the music or film industries, $180.3 billion in 2021 (Wijman 2021). Digital games trend of pedagogical paradigms calling for active constructive, and playful learning. Serious games are considered a major emerging technology that is expected to enter mainstream use, Steiner et al (2015) In parallel, the proportion of citizens declaring dissatisfaction with functioning democracy in their countries has risen markedly. The deterioration has been especially evident within high-income, consolidated democracies, where the proportion has risen from a third to half of all citizens." (Foa et al., 2020). Similarly, the distrust of news sources and scientists fuelled by an increase in fake news is at an all-time low (United Nations 2021). This dissatisfaction and mistrust correlate with increased scepticism. This has occurred in an environment where the volume of date generated through citizens interactions and transactions with media is increasing. The analysis of data has increased to the point that it has significant economic impact with the effect it is argued that social media is polarizing society (Vrontis et all 2022). The GREAT project aims to address this dilemma by applying games technologies to achieve positive transformation restore community engagement and satisfaction with democracy and democratic processes in establishing policy priorities for addressing the challenges presented by climate change. By utilising the opportunities presented by the collection and storage of citizen generated big and small data to bring together communities, in an open, ethical process.

2. Methodology

There are two distinct aspects to the methodology. The first being the overarching methodology applied to delivery of the project, this incorporates all aspects of the successful delivery of the project this is provided in Figure 1 below:

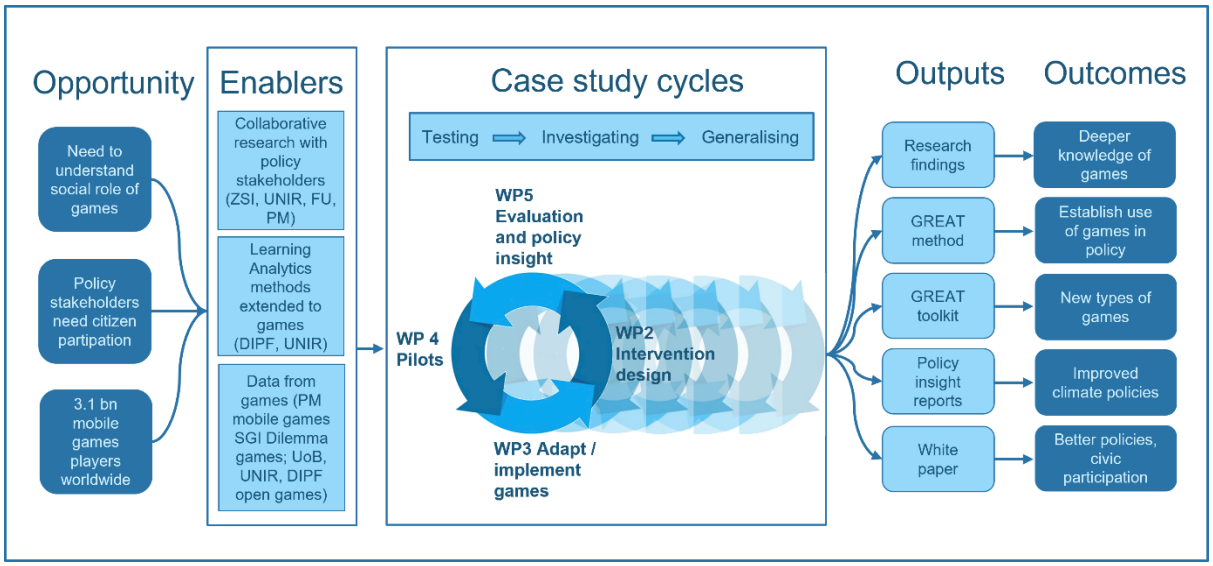

Figure 1: The Overarching Project Methodology

Situated within the overarching project methodology is the research methodology, which is the focus of this paper, specifically the Case Study cycles as detailed in Figure 1 above.

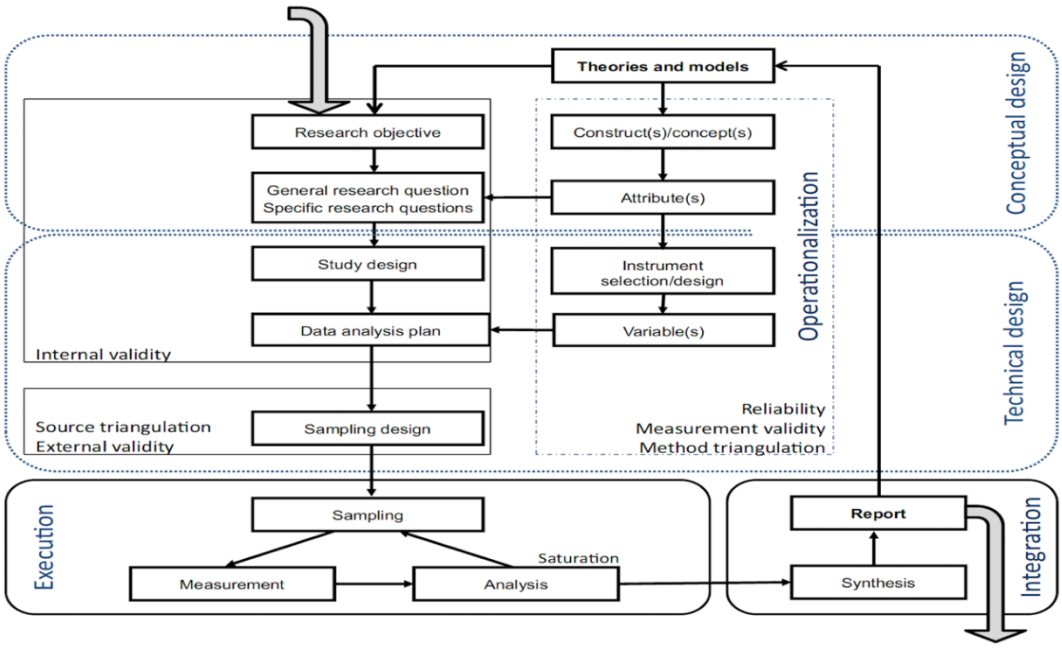

Figure2: An adaptation of the MIR Framework (Tobi and Kampen 2018

The research methodological approach is based on an established interdisciplinary framework an adaptation of the Multi Interdisciplinary Research (MIR) (Tobi & Kampen 2018) framework to refine methods and instruments of research based on synthesis of established community intervention/ co design evaluative methods)

2.1 Conceptual Design: The Research Objective

The research objective of the project is to apply games to gain valuable insight into their cultural role through several case studies, these are analysed and evaluated with a view to examining the efficacy of digital games as communication conduits between citizens and policy makers, transparently and to provide actionable insights.

The project is oriented to the examination and critique of the cultural and communicative value of games as a conduit for citizens who may not normally engage in socioeconomic debates, and could be, potentially, sources of valuable insight for policy stakeholders.

The games and interventions co-designed and implemented within the GREAT project are not bespoke solutions primarily their function is to be deployed as research tools to explore the effectiveness of the approach and pilot methods which could provide rich data sources for future adoption. Our approach to the research is based upon these assumptions:

- Games constitute a rich source of data that can reveal a great deal about players' engagement, preferences, and attitudes. This data is closely guarded by publishers and developers heralded as a competitive advantage to them in optimising their games. It is our contention that this data constitutes a significant opportunity to draw out insights into social preferences and attitudes at scale, this may require new methods of gathering, collation, and analysis.
- The online interactions of game players generate a stream of data, and analytics methods could be adapted to reveal connections between game-world interactions and players' engagement with and attitudes towards their physical world experiences, concerns, and priorities.
- Policy stakeholders are seeking informed insight into citizens preferences and attitudes and could be open to engaging with this input. This assertion is evidenced by the active engagement of policy makers from the European Union in the adoption of the project and the participatory Citizen Science approach that engages stakeholders from the onset an example was the first pilot cycle with the governmental authorities in Frankfurt, Germany.
- Using as an example, the project addresses the global social challenge of sustainability and the climate change crisis. The project also presents opportunities to examine the transferability of the methods developed in the iterative sense as the research is undertaken. Subtopics that have emerged in the exploratory pilots.

include energy costs and consumption, government subsidies for green initiatives, the impact on disadvantaged sectors in society, and transport. These subtopics will serve to inform the development of case studies as the project progresses. The collaborative participation of commercial digital game companies and data analytics academic specialists who will also a focus on economic viability and effective business models (Hollins et al 2018)

2.2 Conceptual Design: The Research Objectives and Questions

The conceptual design of the project research objectives and questions are provided below:

2.2.1 Research Objectives

- To Establish ways in which games can be designed to provide a link between citizens and policymakers.
- To Understand the actual and potential impact that games can have on citizens' engagement in social issues and challenges, and on policy stakeholders' awareness of citizens' attitudes and preferences.
- To Assess the benefits and risks to individuals and society of using games to promote engagement with societal challenges.
- To assess the impact of games and playful techniques on participants' attitudes, knowledge, and behaviour towards climate change, and the effectiveness of different game design elements in achieving these outcomes.
- To develop recommendations and guidelines for policymakers and practitioners on the use of digital games and playful techniques as a tool for engaging citizens in climate change-related decision-making processes.
- To examine the potential of digital games and playful techniques in fostering intergenerational and cross-cultural dialogue and collaboration on climate change issues.
- To develop a framework for evaluating the impact of games and playful techniques on citizen engagement and participation in climate change-related decision-making processes, and to use this framework to assess the effectiveness of the GREAT project's interventions.

2.2.1 Research Questions

- Are digital games effective in providing a link between citizens and policy makers?
- What is the impact of digital games on citizens' engagement in social issues and challenges and on stakeholders' awareness of citizens attitudes and preferences?
- What are the benefits and risks to individuals and society of using digital games to promote engagement with societal challenges?

- What are the most effective types of digital games and playful techniques for engaging citizens in discussions and decision-making related to climate change and sustainability?
- How can games and playful techniques be used to effectively communicate complex scientific and technical information related to climate change to a broad audience?
- What are the potential impacts of games and playful techniques on participants' attitudes, knowledge, and behaviour towards climate change, and how can these impacts be measured and evaluated?
- How can digital games and playful techniques be used to foster intergenerational and cross-cultural dialogue and collaboration on climate change issues?
- How can games and playful techniques be designed to promote empathy and emotional engagement among participants, and how can these emotional experiences be used to motivate action towards climate change?
- What are the potential benefits and limitations of using game-based scenarios and simulations as a tool for testing and evaluating different policy options and their potential impacts on climate change?
- What are the most effective game design elements for promoting engagement and learning in climate change-related games, and how can these elements be integrated into game design?
- How can the impact of games and playful techniques on citizen engagement and participation in climate change-related decision-making processes be evaluated, and what are the most effective methods for doing so?
- How can the insights and lessons learned from the GREAT project be applied to other contexts and settings, such as other global challenges or other fields of research and innovation?
- What are the potential risks and limitations of using games and playful techniques for engaging citizens in climate change-related decision-making, and how can these risks be mitigated?

2.3 Technical Design: The Study Design

Social dilemmas have been represented in games designed to raise awareness. In the context of the climate change crisis this has been characterised as asking players to make decisions to balance potential positive and negative outcomes to provide illustrations of the consequences of their decisions. An example of this approach is 'World Climate' a role-play simulation of the United Nation climate negotiations this game provides feedback on the impact of policy decisions on climate change (Rooney-Varga et al 2018).

Deploying two distinct approaches the GREAT project extends this practice by aiming to capture the interaction data that reflects players disposition to social dilemmas posed by the climate crisis. The first approach of embedded quizzes in commercial games and the second (informed by harvested data from the first approach) supported dilemma based applied games.

- Targeted Data is harvested within the games from focussed samples, Quiz-style games are designed by commercial partner Playmob with mobile devices as the main platform, to effectively capture anonymised player data relating to knowledge, sentiment, and behavioural choices. Players are provided with the additional option to provide supplementary demographic data which will inform the analysis. The primary distribution mechanism is via media embedded within existing popular mobile games. In addition, the quizzes will also be embedded into partner websites and applications related to the social issues of interest or will be accessed via unique QR codes. These options enable audience-specific data streams by geo-location, partner or date or time to be rigorously analysed.
- The moderated dilemma games provide an opportunity to explore topics in greater depth. Expanding on the experience and expertise of applied game developer Serious Games Interactive (SGI) these games will be played by cohorts of players who have agreed to participate for a specified duration. The activities will be stimulated and coordinated by a human facilitator on the game platform. The consequent interactions within these collaborative games will generate opportunities for the collection of rich data and the formulation of insights into climate change policy issues. Inevitably, there is a balance to be achieved between the richness of the data generated in these collaborative games and the number of players that can participate.

2.3.1 The first relates to the dilemma-based learning (Dibl) games which will provide rich qualitative data sets. (Commercial Partner SGI led)

This element of the study design is where the citizen scientific approach to co creation occurs. in Dilemma Based Learning (DiBL), stakeholders participate in the scenarios collectively this is a fully facilitated supported activity. The stakeholder group will discuss and reflect together as the scenarios develop through discussion, With this approach the GREAT project team develop a narrative and support this with images and videos. The stakeholder

groups are involved and challenged in co creating the dilemmas and choices. When the group come to consensus on how the narrative should develop to fully incorporate consequences for actions and symmetric feedback throughout the story. The approach to developing the scenarios is as follows:

- Narrator's perspective

What is appropriate for the stakeholder group 1st, 2nd or 3rd person?

Examples of this are .: 1st person: I am in England, 2nd person: You are in England, 3rd person: Peter is in England.

- Should Short or branching narrative be used?

If several different branches of the story are desired, telling different sub-stories according to the participants' choices. Should the narrative be short and straightforward or be more complex and involve branching?

- Deep involvement of the stakeholders?

What degree of "immersiveness" is desired for the participants (this is dependent upon the narrator's perspective) . Should the stakeholders be personally involved in the story? Should they feel immersed in the story at a visceral level and in how the theme unfolds. Examples could be through role-playing by the facilitator, roles or unexpected external events.

- Fictional or 1:1 with reality? Where would the scenario be geographically located?

Should the story be factually based, or should it be fictional? Where should the story be geographically located?

- A 'Blended' experience or stand-alone digital?

Should the solution only take place in the virtual world, or should there be other elements, such as physical objects? The dilemma can include props (e.g. cards, game board, checkers), actors (e.g. actor), roles (e.g. authorities, groups) or events (e.g. an arrest or action). Draw out knowledge/behaviour in the classroom or do physical things in the classroom that influence choices digitally. Facilitator, stakeholders and externals can, for example, have different roles.

The data generated in the DiBL games could also, potentially, inform the future design of games for social impact in representing the emergent complexity of game play. Emergent complexity (Hollins 2011) is that which emerges from the interactions of the player with the technical environment (each of which is a traceable component) and these interactions being immeasurable and not reducible to the sum of their differences.

The commercial games deployed in the project will be supplemented with non-commercial open-source games developed by the academic partners in the consortium the University of Bolton (UoB), University of Rjoca (UNIR) and (DIPF). This will provide the opportunity to obtain additional data and insight, but with the primary purpose of testing the degree to which the GREAT methods are independent of the technology used to facilitate the research. As opposed to creating sophisticated delivery mechanisms and authoring environments, these open-source games focus on the demonstration of how the process of intervention design, implementation, data gathering, analysis, and generation of insight can be carried out without dependency on proprietary technologies. Open data analytics will be used to analyse both the results of gameplay and interactions with users and stakeholders. 'Data analytics' refers to both statistical methods and machine learning techniques, used pervasively in the media, government, the military, health and education, as well as in policy and science which are the focus of the project.

It (the data and process) is 'open' in the sense that the methods used are exposed and elaborated whilst the data remains confidential and anonymous. Whilst it is recognised that data analytics and indeed artificial intelligence provides insight there are critical ethical considerations that must be accommodated. It is argued (Lewandowsky and Pomerantsev 2022) 'the opacity of algorithms does encourage platforms to drench users in information that may be detrimental to democratic health. Even ignoring the specifics of content, algorithmic opacity also contributes to a general imbalance of power between platforms and users that can only be unhealthy in a democracy' leading to 'a battle between technological hegemony and survival of democracy'.

In this context, the project explores ways in which data analytics can be deployed ethically and in ways that actively reinforce democracy and dialogue, committing to the concepts of open scientific data and open analytics methods (Muslim et al 2020) and in recognising the generated data from confidential information and interactions through channels, workshops and focus groups is appropriately deeply anonymised. Once

anonymised the sources of data will be transparent, the analytics deployed in the project inspectable, and the analytics processes described in plain English terms.

2.4 Citizen Science and Co creation in the research methodological Process.

Co-design, Participation and Citizen Science Participatory methods are applied at the core of the project. The key audiences, including policy stakeholders, will participate and inform the design, prototyping and research phases of the topics to be covered and how best to present them.

It is essential that the project facilitates authentic input, interaction, and collaboration throughout the programme with the target audiences constantly receiving feedback and optimising as the project progresses.

The project will engage with audiences based on the International Association for Public participation (IAP)2 model, which increases the impact on the decision of engaged actors by moving along the spectrum of participation: inform - consult - involve - collaborate - empower. (IAP2 2022) This spectrum of engagement equally will be reflected in the game content itself and the co-design leading to it. Equality, Diversity, and Inclusion (EDI) is a critical element of engaging audiences, and the project has developed the programme to consider accessibility, internet access, health requirements and language needs. A citizen science approach is applied to all aspects of the research. This requires Participation beyond gathering opinions (= consulting), forming part of a research method focussing not on the explicit, quantifiable, and reproductive knowledge of the users but on revealing the tacit aspects of human activity, as Spinuzzi suggests, it is "what people know without being able to articulate" (Spinuzzi, 2005) Following good practice in citizen science, the project offers different degrees of participation from consultation to empowerment.

Stakeholders will contribute to the co-design and choose what kind and level of engagement they want to reach. This can range from co-design of graphic elements to the definition of research questions and the co-analysis of the collected data. The project will run a total of 5 iterative cycles. The first cycle will serve as a Preparatory Cycle with a tightly defined group of internal Test Users. Thereafter, at the start of each new cycle we will hold engagement workshops with around 20 participants in 5 languages (English, Spanish, German, Greek and Danish). The workshops will take place both online and in-person to ease participation and recruiting will be done via the partner networks, to ensure we attract a diverse set of participants. As the project offers different levels of engagement, these workshops will also offer the possibility to engage with the collected data and add a human understanding to the open data analytics (above). At the start of cycle 2 we will hold engagement workshops with policy stakeholders to provide them with a sense of ownership of the project, and we will continue to consult with - and feedback to - these primary stakeholders throughout the project.

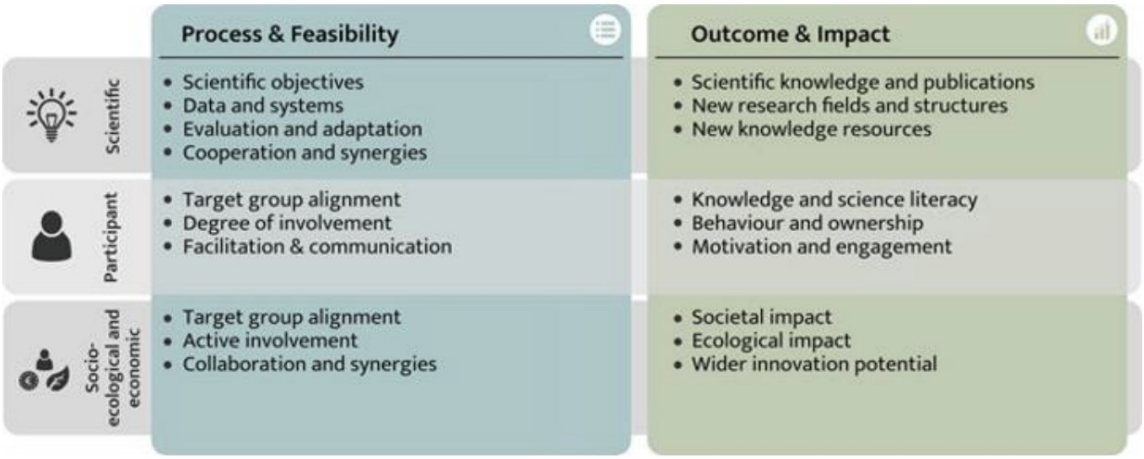

Figure 3: Methods for participatory approach and impact assessment. Keislinger et al (2018)

To assess the effects of the active integration of key stakeholders in the scientific process, we will apply a comprehensive evaluation and impact assessment framework developed by partners Centre for Social Innovation ZSI in Figure 2 above that has been specifically designed and successfully applied in citizen science projects. This framework goes beyond the assessment of scientific achievements and specifically considers impact on the individual citizens, society at large and other socio-economic impacts.

2.5 Technical Design: Sampling Design

Dues to the exploratory nature and scale of the project the use of established (controlled) sampling methods will be limited in the project. For the initial stages 'convenience sample' design will occur through existing networks of the collaborative partners before more controlled targeted sampling will occur.

3. The Study (Cycle) Design Activity

There are two distinct approaches to the cycle design within the great project:

- Cycle phase 1: intervention design. The policy theme and the research questions for the case study are defined in a collaborative process with stakeholders. The games and interventions are designed in a three-stage process, with policy stakeholders and citizens involved in collaborative design throughout, in workshops, focus groups and interviews. Stage one develops design challenges and use cases, answering the question "What will this game achieve and how". It will identify authentic dilemmas which concern them and the kinds of information which they would find valuable, and the user groups who can provide this information. Data from game play, and activities with stakeholders will identify needs for insight, to meet the nuanced needs of our target audience. Publicly available information on the climate crisis and other social issues will be collected and analysed to provide insight into the dilemmas selected by the project. This will help ensure optimal levels of user engagement, satisfy the needs of audiences, and identify opportunities for future iterations. The output of this stage is a design hypothesis, which specifies the expected engagement of users, the usable information which will be generated, and the value that this information will have to policy stakeholders. Stage two develops design briefs, answering the question "What game characteristics are required to meet this design challenge". It will provide detail on the specific issues and challenges raised by a dilemma, identifying or authoring appropriate thematic content, and specifying sources of data, analysis, and outputs. Stage three develops wireframes, answering the question "How can this design brief be implemented", providing a specification which can be analysed for the technical development.
- Cycle phase 2: preparation of case studies, the intervention theme and research questions, and the games activities to inform the research instrument design, and schedule of case study activities defined. In parallel the wireframes produced in phase one will be implemented. Although the main purpose of the GREAT project is not the creation of games, nevertheless the project will produce several new games in rapid development cycles. This is feasible because the consortium includes two commercial games providers whose development systems enable us to reconfigure existing technology for use throughout the duration of the project. A development group will be established to manage the agile development process..
- Cycle phase 3: data gathering and analysis. Activities will range widely from small scale activities to large numbers of users, gathering both quantitative data from the games, and qualitative data from interviews and focus groups. The case studies will seek to answer the research questions and test the design hypotheses developed in phase one. They will involve the whole information flow of game play, data gathering, analysis and engagement with policy stakeholders, evaluating the transferable methods developed by the project. The case studies will also provide feedback on the effectiveness of game designs and the dynamics of communication patterns with user groups. In all cases, the respondents in GREAT research will be volunteers who have given their informed consent to participation. Three different strategies will be used to identify participants in trials:
- Cycle phase 4: conclusions and insight. In this phase the conclusions of the case study are formulated. These include the preparation of scientific outputs for publication, feedback for the design of instruments, processes, and participant engagement. In collaboration with stakeholders, the insight from the cycle is drawn out, insight briefings prepared for policy stakeholders, and their feedback elicited. The GREAT method is reviewed and updated. Phase 4 is carried out in collaboration with stakeholders and constitutes a preparatory stage for the next iteration of the cycle. Engagement and targeting strategies are reviewed and optimised after each cycle.

3.1 The second relates to the quiz games within games approach which in turn we anticipate will we anticipate will supply large quantitative data sets. (Commercial Partner 'Playmob' led)

Quiz-style games are designed to be embedded within mobile devices as the main platform. The function of the quiz is to capture players' knowledge, sentiment, and behavioural choices. Building on the platforms and expertise of commercial partner Playmob, the project will gather a large quantity of responses data from an estimated user base of of 3 million players, with an expectation of a response from 300,000 players based on previous activities. The data is generated from players of the games and from specific targeted subsets of groups

of users. This quantitative data is anonymous, protecting the privacy of players. Players also have the option to provide supplementary demographic data which can inform the analysis.

The primary distribution mechanism of the games is by media embedded within established successful mobile games. In addition, the content can also be embedded into partner websites or applications related to the social issues of interest and these can be accessed via unique QR codes. All options enable audience-specific data streams by geolocation, partner or date/time to be analysed.

4. Conclusions.

In conclusion this paper provides an early summary of the planned methodologies and interventions of the EC funded GREAT research and Innovation project. A project that investigates the potential of digital games and gameplay to engage citizens across Europe through codesign activities to provide input into developing policy priorities on climate change. The GREAT project makes a strong contribution to the impact of the Horizon Europe Strategic Plan by realising this potential (a key sector of the *cultural and creative sector*) to achieve a *continuous engagement with society, citizens and wider economic sectors.* A key contribution is to enable gameplay to become more than entertainment, simulation, or learning, by situating it in authentic social issues.

The GREAT project also conceives and applies innovative data gathering and analysis methods to understand players' attitudes and preferences in relation to policy and closes the loop by feeding them forward to policy stakeholders.

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Teaching with Business Simulation Games: Identifying and Overcoming Hurdles to Adoption

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Abstract: Although the use of business simulation games (BSG) in higher education has grown steadily, there are still many instructors who have never taught with BSG and their use in several academic disciplines remains very low. Existing research has primarily used quantitative surveys to identify the hurdles that prevent faculty from teaching with BSG. This article uses a focus group methodology to further investigate the obstacles to using BSG and subsequently applies a change management framework to identify levers that can be used to promote the use of BSG. The obstacles to adoption are classified into categories of suitability, risk and resources. Focus group participants expressed concerns over the suitability of existing BSG for their courses and the expected time required to identify, evaluate and prepare to teach with BSG. These factors made most focus group participants consider teaching with BSG as fraught with risk. In response, universities can encourage faculty to start using BSG in their teaching through the provision of resources, information and training, and through organizational adjustments such as incentives and flexibility to adjust course syllabi. A full range of measures is identified and the environmental contexts in which each one is likely to be effective are discussed. The individual levers that can bring about change have different environmental contexts in which they are likely to be effective.

Keywords Business education Change management Simulation games Technology adoption Higher education

1. Background

Business simulation games (BSG) have received increasing attention due to their potential to motivate student learning, replicate the dynamic and interdependent environments found in the workplace and thereby turn students into active learners (Hallinger & Wang, 2019; Salas, Wildman & Piccolo, 2009; Sitzmann, 2011). However, since their introduction in the 1970s, BSG have only partially fulfilled their promise. Although the use of BSG has grown, particularly in North America (Faria, Hutchinson, Wellington & Gold, 2009; Wolfe, 1993), there are still many instructors who have never taught with BSG and in several management disciplines their use remains very low (Faria & Wellington, 2004). The reluctance to use active learning methods in general and BSG in particular has been partly attributed to the perceived costs of using alternatives to lectures, including the expectation of additional preparation time (Goffe & Kauper, 2014; Cadotte, 2016). Other faculty may simply be resistant to changing teaching methods they are comfortable with (Tagg, 2012) and be fearful of looking ignorant if they are unable to explain the activity to students and fail to help them to improve their results (Cadotte, 2016).

This article develops a framework to analyze the reasons why instructors in higher education choose not to teach with BSG and identifies possible interventions to help alleviate the obstacles to adoption.

2. Literature review

Simulation games have been defined in the literature as “Internet-based, synthetic learning environments where decisions are made within a complex and dynamic setting, and where students experience real-time information and feedback” (Lovelace, Eggers, & Dyck, 2016).

Since 2000, the increase in bandwidth, the extension of internet access to students and the growth in availability of high-quality and relevant games has promoted the use of BSG in higher education. If, in addition, the benefits of using experiential learning methods in general and BSG in particular are now well known (at least in the literature), the question arises why there is still such a large proportion of university faculty that refrains from using them in class. The existing literature partially addresses this question through surveys. In Faria & Wellington (2004), faculty who had never used BSG were less likely to have received information through emails, colleagues, sales representatives or other methods than users. In fact, their study found that only 26 per cent of never-users were “somewhat familiar” or “very familiar” with business games and this lack of familiarity clearly inhibits adoption. Within each of the respondent groups (users, former-users, never-users), a majority of respondents did not even

know where to look for information on BSG. Never-users who had actively considered using BSG have refrained from doing so primarily due to the expectation of additional preparation time. Other reasons mentioned in the study were, in order of frequency of responses; a poor fit with the course, lack of information, preference for an alternative pedagogy, class time it takes to run a simulation, funding, administration issues and technical issues.

Moizer, Lean, Towler & Abbey (2006, 2009) investigated barriers to adoption of BSG through quantitative (Moizer et al, 2006) and qualitative studies (Moizer et al, 2009). They classified barriers in terms of suitability, resources and risk. In their framework, suitability refers to the need to ensure that BSG are directed towards the intended learning outcomes. Resources include financial costs, administrative and technical support, and instructor time, which in turn consists of time required to prepare, deliver and assess simulation-based learning. Risk includes factors such as potential student resistance or negative reactions, technical issues and loss of control over student learning. They conclude that instructors make their decision on the use of BSG based on perceived benefits and risks. The research showed that the only resource that was identified as a significant barrier is instructor time and this is in fact mentioned as the largest single obstacle to adoption. Lack of available instructor time will in turn have an impact on the possibility to manage issues related to suitability and risk. In other words, instructor time is needed to identify and test suitable BSG and to manage risks when using them in class. Actions that were suggested to overcome the obstacles include freeing up teacher time and providing support through training and information sharing.

Justice and Ritzhaupt (2015) developed a survey instrument to analyze the barriers to using BSG in education with a total of 32 potential barriers. Their survey was administered among users and non-users of BSG and included teachers at schools and universities. The highest rated barriers to adoption of BSG included the cost of equipment, lack of time to plan and implement, inability to try before purchasing, lack of balance between entertainment and education, lack of available lesson plans/examples, lack of alignment to state standards/standardized testing, inability to customize a game/ simulation, and inability to track student progress within the game/simulation. Although the authors themselves categorized the barriers into 7 factors, most of the barriers listed as important can also be classified by using the framework of suitability, resources and risk put forward by Moizen et al (2006). Cadotte (2016) also referred to the issues of risk and resources, when he wrote that “instructors are fearful that they will look bad” and “in an environment where the publication of scholarly research is the number one goal, less labor intensive learning options tend to take precedence.”

In summary, the use of BSG in higher education generally and management education specifically has increased over time. The existing literature has two major limitations. First, most research is based on surveys of faculty, with closed answers. Such an approach is valuable in terms of obtaining quantitative data and insights, but it does not offer the opportunity to explore the interplay between different factors at work. The main themes of concerns over suitability, risk and resources are interrelated and do not lend themselves well to analysis through a straight comparison of responses on a survey. Secondly, the existing research focuses on obstacles to adoption but says little about how these obstacles can be addressed by various stakeholders. Although the identification of obstacles to adoption is a valuable first step, the design of measures to increase adoption does not flow naturally from survey results. In response, this paper develops an understanding of the interplay of obstacles to adoption and the measures that may be taken to alleviate these obstacles on the basis of focus group discussions.

3. A framework for overcoming hurdles to adoption of BSG in higher education

If the adoption of BSG in teaching can be viewed as an exercise in change management, then the BSG entitled “Change Management Simulation: Power and Influence” distributed by Harvard Business Publishing (Judge & Hill, 2018) provides a potentially useful framework to analyse the obstacles and define levers that can bring about change. The simulation develops participants’ skills in leading strategic change in a sunglasses manufacturing company. As the teaching note explains (Judge & Hill, 2018), the game is based on a range of theories and frameworks developed in the change management literature. This paper does not delve into the origins and details of the underlying theories behind the framework, but simply applies them to the context of resistance to adoption of BSG.

In “Power and Influence”, players act as a change manager in the company, taking company employees through four stages of change; awareness, interest, trial and adoption. In the game, learners can employ a combination of 18 change levers to influence company stakeholders. There are four types of employees in the organization (“change targets”); early adopters, early majority, late majority and resisters. Over different rounds of play, players choose

which levers to use in order to move a critical mass of staff through the phases of change from awareness towards adoption of the new way of working, while at the same time aiming to minimize the cost of the change. There are three contextual variables that impact the scale of the challenge: the power of the change agent (low/high), the urgency of the change (low/high) and the receptivity of the change targets. Within each organization there is likely to be a range of staff members, some in favor of change and some unwilling to change.

The adoption of experiential learning methods and BSG in higher education can be analyzed through the lens of the change management framework used in the BSG "Power and Influence". The challenge to increase adoption of BSG at a university is significant because both the urgency of change and the power of the change agents can be considered to be low. Even if the College Dean is fully behind an initiative to promote experiential teaching methods and holds formal authority over the faculty, there is a limit to the extent to which leadership can oblige faculty to adopt particular teaching methods. College Deans may also be reluctant to make resources and time available for the adoption of BSG if this goes at the expense of resources devoted to academic research. The urgency of moving towards experiential learning methods can also be considered low, although the COVID-19 crisis has created a new sense of urgency to the adoption of technology enabled teaching methods.

The third contextual variable in the BSG "Power and Influence" is the receptivity to change among staff members in the organization. In this analogy, the change targets consist of university faculty. Dorbala & Rana (2019) concluded that there is strong resistance among faculty towards using technology in teaching, although faculty members at any university are likely to encompass the full range from early adopters to resisters. In summary, when applying the structure of the BSG "Power and Influence" to the change effort needed to get faculty to teach with BSG, the contextual variables can be characterized as consisting of a perceived low urgency for change, a change agent (the Dean) with limited power and a group of change targets (the faculty) with varying but generally low levels of receptivity to change.

The status of these contextual variables in turn determine which change levers are likely to be effective in promoting the successful adoption of BSG. In the scenario of low urgency and low power of the change agent, the authors of "Power and Influence" recommend an approach of evolutionary change where credibility is built up over time. If events such as the COVID-19 crisis increase the urgency, then the prescribed approach is one of accelerated change. If, at a particular university, the power of the change agent is high, then credibility does not have to be built up but needs to be preserved.

4. Focus groups

In order to understand the interplay between different obstacles to adoption to BSG and the appropriate levers to encourage adoption, a focus group discussion was selected as the appropriate research methodology. Focus groups provide an efficient method for obtaining data from multiple participants and the social interactions between participants can help them to feel safe to share information and to solicit spontaneous responses (Onwuegbuzie, Dickinson, Leech & Zoran, 2009). Existing research on obstacles to adoption of BSG is primarily based on questionnaires, which are useful to identify items and their importance from a statistical point of view. In contrast, the focus group format enables a deeper analysis of the interrelationships between the various obstacles and the different interventions that are identified to alleviate these obstacles. Focus group discussions can help identify points of importance through the intensity and specificity with which comments are made (Krueger & Casey, 2014).

Participants were all experienced academics at a College of Business in the United Arab Emirates, representing a wide range of nationalities and academic disciplines, including Management, Human Resources, Leadership, Organization Behavior, Accounting, Finance, Business Law and Economics. Participants were predominantly teaching in undergraduate degree programs, with limited teaching in postgraduate and executive education programs. There were 11 participants in total, all with significant experience in academia (5 years or more). Five participants had experience of BSG as a student and two had some previous experience of teaching with BSG, but not necessarily as the principal instructor. None of the participants were currently active users of BSG in teaching and each participant was thereby able to contribute to the discussion on why they were not current users of BSG. Participation in the focus group discussion was voluntary and a result of an invitation from the author to faculty colleagues. The invitation specifically invited faculty members who are not currently using BSG. All participants were from the same institution, located across two campuses in different cities.

Each focus group discussion had the same structure and lasted around 45 minutes. Discussions were held virtually and were recorded for subsequent review and analysis. After a brief introduction to define the term BSG and explain the purpose and format of the discussion, participants were asked to share their experience to date with BSG, discuss the perceived potential benefits of teaching with BSG, mention obstacles that prevent them from trying or adopting BSG and finally discuss ways in which these obstacles could be overcome. For the sake of ease of interpretation, the discussion below does not distinguish between results from the two sessions.

After coding, the comments were analyzed to identify emerging themes. In addition, the recording of the focus of group discussions were watched several times in order to note not only the contents of what was said but also the intensity and specificity of various contributions to the discussion. What follows is a summary of the main themes that emerged from the focus group, in the same order in which they were discussed. As an introduction into the topic, participants discussed the perceived or expected benefits of using BSG, followed by the two main research questions regarding the obstacles to using BSG and the levers that can be used to address these obstacles.

4.1 Perceived benefits of BSG

All participants knew what was meant by BSG after the term was explained to them. Some had memories of using BSG as a student and remarked that these experiences represented the most memorable parts of their studies. Some participants were also aware of colleagues, mostly at other universities, who are teaching with BSG. The participants of the focus groups had varying levels of awareness and interest in BSG, but only two had tried to use a BSG in class and none could be classified as regular adopters.

When asked about the potential benefits of BSG, participants mentioned increased student engagement and enthusiasm, the ability to link course materials to the workplace and the opportunity to enhance learning. It appeared all participants were aware and convinced of the potential benefits of BSG and nobody argued that they are inappropriate or have no advantages over traditional forms of teaching. In an age of technology proficient students, it was mentioned that teaching with technology is a natural choice. Several participants remarked that they were not quite sure why they had not yet started teaching with BSG, indicating a willingness to adopt BSG but apparently attaching a low priority to realizing their intention.

4.2 Obstacles to using BSG

The question on obstacles to adoption provided responses, which can be broadly classified according to the categories of suitability, resources and risk advanced described above (Moizer et al, 2009). In terms of suitability, the main obstacles consisted of the lack of awareness of suitable games and the expectation that there are no suitable BSG available for the courses taught. There was an expectation that there would be no suitable BSG available for introductory courses in a range of disciplines or for courses with a strong element of localized content, for example Business Law. Another concern around suitability was the expectation that available BSG would not adequately match the learning objectives and terminology of the courses being taught. If a BSG would introduce new concepts that are not part of the course or would not cover certain topics that are part of the course (or section of the course), then these BSG would be considered as not suitable. One participant also expressed the expectation that it would be difficult to track student progress when teaching with BSG. A final point on suitability relates to the perception that the use of BSG takes up class time and needs to go at the expense of something else, for example lecturing. With a full course schedule, participants expected it to be challenging to allocate class time to the use of BSG.

Resources and risk were advanced as the most pressing concerns regarding the use of BSG. The views on license fees being an obstacle were mixed, but there was a general expectation that they could be an issue. For one instructor the cost of a BSG in conjunction with an e-book was considered excessive. Uncertainty about the steps required to get budget approval and arrange payment for BSG were also mentioned. More importantly, faculty time was mentioned as the overriding resource constraint, with participants expressing their concerns with a high level of intensity and specificity. Participants mentioned the time required to identify a suitable BSG, to prepare for teaching with it, to adapt course assessments and change the syllabus to take into account the introduction of BSG. Several participants also mentioned the time required to coordinate with other instructors teaching the same course within the same institution, in a context where consistency is required for different sections of a course. Time required to find out about the administrative processes for payment was also mentioned as a concern. In short, participants expressed the expectation that teaching with BSG would be very time consuming and that there 'simply isn't the

time' to do all this in context of existing commitments in the areas of teaching, administration and research. Most participants agreed with the view that the adoption of innovative teaching methods such as BSG was not incentivized relative to academic research or service.

Participants pointed out various risks associated with the use of BSG. Some were concerned that an experience with BSG would not be positive for students and leave them frustrated. This risk was regarded as particularly high if an instructor is uncertain about the suitability of a BSG and does not have sufficient time to properly prepare for teaching with it. The issue of relevance for a course was emphasized repeatedly, with participants expressing a fear that a BSG would not be appropriate for a particular course and could therefore be of little or no benefit to student learning. In such cases, participants feared a backlash from students from the use of a BSG. The issue of risk was related to resources in that participants felt they would need to spend a great deal of time on evaluation of BSG and preparation for class in order to improve the chances of success. One participant mentioned he was new to the university and is already investing time to adapt to a new set of circumstances. He preferred to "get the basics right" during the first year, before embarking on more experiential approaches.

Most participants did not see technology as a major risk factor. Only one participant was concerned that if somehow the technology fails, then the experience for instructor and students would not be positive.

The obstacles to adoption of BSGs mentioned in the focus group discussion are listed in Table 1.

Table 1: Summary of obstacles to adoption

Suitability concerns	Resource issues	Risk
Lack of awareness of suitable games	License fees	Unsuitable SG risk achievement of course objectives
Expectation that no suitable games are available	Time required to identify suitable SG	Technology
Not knowing where to look for SG	Time required to prepare teaching with SG	Insufficient class time
Need for localized content	Time required to adapt assessments and syllabus	
Need to match learning objectives and terminology of courses taught	Need to coordinate with other teachers	
SG should not introduce concepts that are not part of the course	Administrative processing	
Difficult to track student progress		

In summary, although participants were in agreement about the potential benefits of using BSG in class, they had generally not taken steps towards adoption of BSG due to the expectation that there are no suitable BSG available, time constraints and perceived risks. In relation to the existing literature that investigates obstacles to adoption of BSG, the focus group participants were able to be highly specific about their concerns and the linkages between them, which in turn served as a basis for the discussion of the levers that can be used to promote adoption of BSG. In particular, participants identified the interrelationship between resources, risk and suitability, in the sense that they felt that their lack of time made it difficult for them to identify and evaluate suitable games, and to prepare sufficiently. These time constraints made participants view the use of BSG as risky.

4.3 Change levers

The next part of the discussion dealt with potential levers that can be used by various stakeholders to overcome the obstacles that were identified and to promote adoption of BSG. Stakeholders in this context may include university management, other faculty members or publishers of BSG. In order to overcome the perceived issues related to suitability of BSG, participants suggested initiatives by publishers of BSG and university administrators to share information available on BSG. Ways to raise awareness include the organization of presentations, as well as training or information sharing sessions for faculty members.

In order to address concerns around time required to prepare teaching with BSG, one common theme of the suggestions that were raised is the need for encouragement and flexibility by university administration. Encouragement can come from the above-mentioned information sharing and training initiatives.

A clear communication of budget availability and the approval process for the purchase of licenses were also mentioned as helpful. Flexibility can be introduced by relaxing, at least partially, the requirement for consistency between course sections in order to encourage experimentation with BSG or other teaching innovations. Although participants were generally not aware of the support materials available by BSG publishers, they felt that clear and concise teaching notes would help them in reducing the need to prepare to use BSG in class.

In order to address the concerns that teaching with BSG is risky, the comment was made that teaching with BSG requires some tolerance for risk and the ability to deal with unexpected situations in class. Focus group participants expected that the receptivity to change varies among both experienced and novice instructors. In order to alleviate excessive risk aversion, university administrators can encourage experimentation and responsible risk taking through encouragement and recognition of the use of BSG, for example in the faculty evaluation process.

The emphasis in the comments on potential actions by the university is noteworthy and is more likely a result of the organizational context of the particular university than the profile of the focus group participants.

In summary, if the adoption of BSG, and of innovative experiential teaching methods in general, is identified as a priority by the management of institution, there are several steps that can be taken in order to address concerns of suitability, resources and risk among faculty. The levers that university or college management can apply are summarized in Table 2 and divided into three types: resources, organizational and information/training. For each lever, it is indicated which obstacles are being addressed and whether there is particular change context (in terms of power of the change agent and urgency of change) in which it is most likely to be effective.

Table 2: Change levers by type

Lever	**Appropriate context**
	(power of change agent/urgency of change)
Resources:	
Make budget available	All scenarios
Allocate instructor time to identify and prepare for use of SG	High power of change agent
Enhance IT infrastructure	All scenarios, depending on existing IT facilities
Information/training:	
Staff training (optional)	Low power of change agent/low urgency of change
Staff training (mandatory)	High power of change agent/High urgency of change
Information sharing (at faculty meetings)	High power of change agent/High urgency of change
Information sharing (online)	Low power of change agent/Low urgency of change
Provide listing of suitable SG	Low power of change agent/Low urgency of change
Organizational:	
Clarify and share process for funding	All scenarios
Adjust incentive structure to reward use of experiential learning and SG	All scenarios
Relax requirement for consistency across course sections	All scenarios
Provide flexibility to make changes to course syllabus, if required	All scenarios
Incorporate use of experiential learning and SG in faculty performance evaluation	High power of change agent
Enhance available IT support	All scenarios
Mandate use of SG	High power of change agent/High urgency of change

Relating these levers to the obstacles that they are designed to address, it appears that several minor organizational changes that encourage experimentation and reward innovative teaching practices can go a long way to encourage faculty to seriously encourage using BSG in class. If faculty get the freedom, incentives and encouragement to experiment, they are more likely to invest the time required to identify suitable BSG and accept the risk they perceive as being associated with them. If the power of the change agent (most likely the Dean) is high or the urgency of change is high, then interventions with a more compulsory nature become possible.

Although all these levers result from focus group discussions that were held in the specific context of adoption of BSG, they can to a large extent also be applied to other innovative teaching methods, including all types of experiential learning and technology enabled education.

5. Conclusions

An analysis of the obstacles and potential levers to affect change has resulted in a range of actions that can be taken by university management and by BSG publishers. Obstacles to adoption of BSG were generally similar as those already identified in the literature, but the need to alleviate time constraints as a prerequisite for dealing with concerns around suitability and risk, was an important new finding. The levers that are controlled by university management to address the obstacles can be classified into availability of resources, provision of information and training, and organizational changes. Not all levers are appropriate in all circumstances and several levers have a particular organizational context in which they can be expected to be most effective. Notwithstanding the need to consider an institution's individual circumstances, an overriding conclusion from the focus group discussion that complements the existing literature on the topic is that universities can encourage the adoption of BSG through several simple organizational initiatives, primarily by giving faculty freedom, incentives and encouragement to experiment with BSG.

This study has identified the obstacles and potential levers related to BSG adoption in the specific context of business education at one university. The research design of using a focus group approach within one university inevitably has some limitations. A focus group discussion limits the sample size of responses from faculty and thereby increases the possibility that the findings are not generalizable. The same concern arises with all participants coming from the same institution. Future research can usefully address whether the obstacles and change levers are different in other contexts, such as in other academic contexts and different universities. The same framework can also be used to address obstacles to the adoption of other innovative and technology enabled teaching practices.

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Investigating Inclusivity in Game-Based Learning: Current Practices and Multistakeholder Perspectives

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Abstract: This study aims to examine how inclusivity measures are understood and applied in game-based learning (GBL). It considers the perspectives of various stakeholders, such as educators, game designers, and students. The focus is on creating accessible and engaging games that meet the diverse needs and characteristics of players. The methodology adopted a combination of primary and secondary data sources to pursue these aims. The primary data collection involved focus groups with educators, game designers, and students. The study employed a participatory design approach, involving multiple stakeholders in the exploration of inclusivity measures. The data collected from the focus groups, along with findings from the literature review, helped in formulating a set of inclusivity metrics for educators to create educational games that cater to diverse student needs. The obtained results emphasize the limited state of analogue GBL accessibility in scholarly and professional literature, while emphasizing the existing frameworks to be adopted by educators, designers, and publishers. Stakeholder discussions revealed themes related to inclusivity measures, including motor, sensory, and cognitive needs of players. Game designers can enhance accessibility by considering these requirements and incorporating alternative communication channels, accessible cues, adaptable gameplay options, and diversified knowledge-based requirements. In addition to inclusivity, addressing instances of exclusion, managing teams effectively, promoting inclusive communication, and incorporating gameplay limitations, educational components, diverse perspectives, and real-world applicability are discussed as important in education game design, to this extent.

Keywords: Game-Based Learning, Educational Game Design, Higher Education, Inclusivity, Diversity.

1. Context

The present study was conducted within the scope of TEGA (2020-1-UK01-KA203-079248), a project that aims to foster change in Higher Education (HE) by employing analogue Game-Based Learning (GBL) approaches for delivering consistent playfulness and reducing existing barriers and obstacles for students. The use of analogue/board/tabletop games has cost, deployment, adaptation, and player engagement advantages over digital games (Marco et al., 2012). Analogue games encourage player participation in ways that digital games do not, as players must "activate" the various game components in order for the game to function (Maratou et al., 2023; Sousa et al., 2023). Successfully employing an analogue games approach for the requirements of GBL requires recognising the needs of each student's learning process, thereby empowering teachers to meet them (Sousa et al., 2022).

This work is a research component of the TEGA Toolkit (https://doi.org/10.6084/m9.figshare.23715942.v1) and addresses the concepts and skills required of instructors and designers in order to accommodate player needs when designing or modding a game. More specifically, the purpose of this study is to investigate the understanding and implementation of inclusivity measures in GBL, taking into account both the current state of the art and the perceptions of multiple stakeholders – including educators, game designers, and students – while emphasising the importance of designing accessible and engaging games that cater to a wide variety of player needs and characteristics.

2. Introduction

GBL has become increasingly pertinent in the field of education in the 21st century, primarily as a result of the changing educational environment and advancements in technology (Qian and Clark, 2016). Although digital games frequently receive more attention, it is important to recognise the potential of analogue games. Analogue games, encompassing board games, card games, and tabletop role-playing games, possess distinct advantages that render them particularly pertinent within modern educational settings (Pomichal et al., 2023; Sousa and Bernardo, 2019).

An important benefit of analogue games lies in their capacity to facilitate in-person social interaction and collaborative engagement. In an era characterised by heightened interconnectivity facilitated by digital devices, analogue games present a valuable avenue for students to actively participate in substantive, face-to-face interactions with their fellow peers (Fjællingsdal and Klöckner, 2020; Wu et al., 2014; York, 2020). This not only facilitates the advancement of social and emotional growth (Dell'Angela et al., 2020; Hromek and Roffey, 2009)

but also fosters the development of crucial communication, negotiation, and teamwork abilities that are in high demand in the contemporary labour market (Reuter et al., 2021).

Analogue games also offer a concrete and hands-on educational experience. The act of physically manipulating cards, tokens, and game pieces by players can effectively enhance sensory engagement and reinforce learning through hands-on interaction. The tactile nature of analogue games can offer significant advantages for individuals who excel in a hands-on and immersive learning setting (da Rocha Tomé Filho et al., 2019; Tsong et al., 2012).

Additionally, analogue games frequently foster the development of strategic thinking, problem-solving skills, and the ability to make critical decisions (Kaya et al., 2017; Mustata et al., 2019). In order to advance or achieve success, players are required to engage in the process of analysing the current state of the game, evaluating various options, and subsequently making well-informed decisions. The cognitive abilities discussed are of great significance in the contemporary era, as individuals frequently encounter intricate challenges and must engage in critical thinking to effectively navigate a world abundant with information.

As understood through this introduction, the current discourse surrounding analogue GBL extensively examines its complete pedagogical potential. However, it is crucial to acknowledge the dearth of attention given to diversity, inclusion, and accessibility concerns within the research conducted in this domain. In this particular context, the comprehension and execution of inclusivity measures have emerged as pivotal considerations. The principal aim of this study is, therefore, to examine the comprehension and implementation of inclusivity measures in GBL. Through a comprehensive analysis of contemporary advancements in the field, this study endeavours to identify the prevailing lacunae and constraints in existing knowledge. Furthermore, the primary objective of this research is to develop a comprehensive understanding of the perspectives held by various stakeholders, including educators, game designers, and students, with regards to inclusivity in GBL.

3. Methodology

This study employed a combination of techniques, utilizing both primary and secondary data sources, to investigate the necessary and current measures implemented to promote inclusivity within the higher education levels ranging from four to seven. The present study incorporates secondary data, which encompasses theoretical frameworks derived from existent literature and industry best practice. By adopting this approach, the study was able to establish a solid foundation in well-established theories and draw upon up-to-date knowledge. The primary data collection process consisted of three distinct stages, with the initial stage involving focus groups, with a total of 35 participants. The focus groups were carried out for a duration of three weeks and comprised three distinct groups of participants: educators, game designers , and students. The rationale for dividing the participants had two primary components. Initially, the inclusion of diverse viewpoints from both providers (educators and game designers) and recipients (students) was facilitated. Furthermore, it served to mitigate the potential for undue influence of more knowledgeable participants, namely educators, on the perspectives of less experienced participants, specifically students.

Each and every participant involved in the focus group possessed a minimum of one prior experience in the domains of teaching, designing, or engaging in the process of learning through game-based methodologies. The study received approval from the ethics committee of London South Bank University. The focus group meetings were conducted in a face-to-face format for students and game designers, while virtual platforms were utilized for educators. The study employed a participatory design approach as its research design, wherein stakeholders were actively involved in the exploration of inclusivity measures. The focus group discussions yielded significant data regarding the viewpoints and perspectives of the stakeholders engaged in the study. The aforementioned data, in conjunction with the findings derived from the literature review, played a crucial role in shaping the formulation of a comprehensive set of inclusivity metrics. These metrics were specifically devised to aid educators in the creation of educational games that effectively address the varying requirements of a diverse student population.

This study sought to offer practical guidance and tools for educators in the design of inclusive educational games by utilising a participatory design approach and integrating insights from focus group discussions and existing literature. The primary objective was to optimise the educational encounters of students at the tertiary level, specifically those in the fourth to seventh years, through the identification and resolution of their varied needs, while concurrently fostering an environment of inclusivity within the context of GBL (Bryman and Bell, 2021). Each session had a duration of approximately one hour.

4. Results and Discussion

4.1 State of the Art in Analogue Gaming Accessibility

According to Heron et al. (2018), the subject of accessibility in board games has received limited attention in scholarly and professional literature. These authors' approach – *Meeple Centred Design: A Heuristic Toolkit for Evaluating the Accessibility of Tabletop Games* – represents one of the first and most significant ones in this field. It is a framework for assessing the accessibility of board games. The adoption of this framework by designers and publishers would be a step forward in addressing accessibility and inclusion. However, the authors acknowledge that a more sustainable solution would require the development of compensatory regimes that utilize digital and analogue technology.

Later, Sousa et al. (2023) found that accessibility and inclusion were not frequently approached in a systematic literature review on analogue GBL. Despite the perception that the board game community is particularly welcoming and inclusive, it seems that these aspects are not a major focus in research. However, the study also highlighted the potential of board games in promoting a sense of inclusion in learning processes. This notion was corroborated by the studies of Sousa (2020) and Veldthuis et al. (2021), based on their potential to cultivate a sense of inclusivity within the realm of learning. This can be attributed to their ability to facilitate the development of a wide range of soft skills, as well as their capacity to accommodate individuals who may not possess a particular disability or condition, such as those who are introverted or possess divergent thinking abilities.

Through a more empirical lens, and by interviewing 18 experts from four European countries, Maratou et al. (2023) showed the existence of heterogeneous perceptions regarding the implementation of inclusivity measures in GBL, since each interviewee had a different way to answer the question "What measures of inclusivity are being practiced within GBL classes?". Some did not see inclusivity as a problem or had not needed to consider it before. Others had to deal with very specific problems faced by students, and yet others described cultural and language differences as the biggest issue. As such, each participant had to consider inclusivity from a different angle, depending on their specific classroom. For example, some interviewees discussed using symbols, rather than letters, to be more inclusive of students with dyslexia. This differs from the approach taken by others, whose main issue was related to cultural differences. They advocated that educators must be flexible and creative in order to solve these issues. One would imagine reducing the reliance on words by using symbols could be a pragmatic example of this and may also help with the issue they mention. The overall picture from interviewees shows how every class-room is different, and each will face its inclusivity issues. GBL itself is a good inclusivity measure, reducing the barriers between people and allowing increased collaboration.

TEGA's first approach to accessibility and inclusion was through the development of a conceptual framework based on the implementation of the different disability paradigms to the field of games and GBL. The framework was based on a study aimed to explore accessibility in analogue gaming and develop an inclusive methodology for the TEGA project. The results showed that game designers need to be aware of disability paradigms and consider contextual factors in making tabletop games accessible. It also emphasized how the different dimensions of accessibility needs, such as motor, sensory, and cognitive, can be addressed through practical features in gaming. Inclusive design involves including the voices and representations of players, both with and without disabilities. Therefore, a conceptual framework for incorporating accessibility needs in analogue gaming was proposed, centered around inclusive design and intersectional accessibility (Sousa et al., 2022).

4.2 Inclusivity Measures in the Focus Group Discussions

Games are selected for utilisation in TEGA instruction within the classroom, taking into consideration the specific needs and characteristics of the intended student population. Educators have the option to use a diagnostics package that encompasses suitable rubrics in order to ascertain the cohort's inclinations towards their roles as players and learners. The rubrics aim to cultivate a comprehensive view of players and learners and to facilitate the identification of appropriate outcomes for the subject and syllabus under investigation, based on their specific needs (Sousa et al., 2022).

The focus group discussions yielded a number of recurring themes pertaining to the utilisation and implementation of GBL. The subject of assessment emerged as the most prevalent theme, as participants engaged in discussions regarding the delineation of failure, the utilisation of games for teaching and evaluating soft skills, the assessment of specific soft skills, the implementation of peer assessment, the adoption of assessment frameworks, the suitability of games as assessment tools, and the execution of comprehensive evaluations of learning outcomes. The participants in the study discussed their personal encounters with

exclusion from games, proposed strategies to promote inclusivity, highlighted the significance of efficient team coordination and communication, and examined challenges such as language barriers and insufficient attentiveness in educational settings that incorporate GBL. This theme emerged as the second most prominent topic of discussion among the participants. The participants articulated several key themes during the discussion. One theme that emerged was the importance of establishing well-defined gameplay restrictions. Another theme was the incorporation of educational elements within games. Additionally, participants emphasised the value of embracing diverse ideas and perspectives. Furthermore, participants recognised the significance of fun and enjoyment in educational games. Lastly, the creation of meaningful connections between game experiences and real-world contexts was highlighted as another important theme.

In a second phase of the qualitative analysis, the team focused only on the discussed aspects related to the different inclusivity measures. The obtained results are aligned with this premise and allowed the project to systematize a set of measures considered as relevant by the different stakeholders in the analogue GBL process — educators, game designers, and students — identified through the analysis of the focus groups, and represented in Table 1.

Table 1: General inclusivity measures and related aspects discussed by the stakeholders in the focus groups

General inclusivity measures	Discussed Aspects
Motor needs	Size of cards
	Token shape
	Regularity of piece manipulation
	Ease of communicating instructions
	Physical acting
	Paper money
	Number of tokens
	Size of game board elements
Sensory needs: visual	Reading level required
	Lying and/or bluffing
	Communication of strategy
Sensory needs: auditory	Audibility
	Lying and/or bluffing
	Communication of strategy
	Need for audible communications
Cognitive needs	Reading level required
	Game state complexity
	Memory requirements
	Game flow
	Number of token combinations
	Synergy of rules
	Scoring

General inclusivity measures	Discussed Aspects
	General knowledge requirement (e.g. trivia)
	Multitasking requirements

According to the obtained results (Table 1), a number of recurring themes were identified in relation to the implementation of inclusive measures and their influence on different facets of gameplay. The participants engaged in a comprehensive discussion regarding the motor, sensory, and cognitive needs of players.

Multiple aspects pertaining to the motor requirements in gameplay were discussed. The factors considered in the evaluation encompassed various aspects, such as the dimensions of cards and tokens, the frequency of piece manipulation, the effectiveness of communicating instructions, physical interaction, the utilisation of paper currency, the quantity of tokens, and the dimensions of game board elements. The significance of taking into account these factors was underscored by the participants, as it is crucial for promoting inclusivity and facilitating the engagement of players with diverse motor abilities. By taking into consideration these various elements during the process of game design, developers have the ability to craft inclusive and captivating experiences that cater to a wide spectrum of players.

Regarding sensory needs, most specifically related to visual abilities, the participants emphasised the significance of addressing sensory needs related to the visual modality. This encompassed the assessment of the dimensions of game board components in order to guarantee optimal visibility for all participants. The discussion also encompassed the reading proficiency necessary for understanding game components or instructions, as well as the inclusion of elements involving deception and/or bluffing, and their dependence on visual cues. Additionally, an investigation was conducted on the transmission of strategies using visual modalities.

Still on sensory issues, participants explored needs related to hearing. This included the perceptibility of sounds or cues related to the game emerged as a significant factor to be taken into account. The attendees engaged in a discourse regarding the impact of auditory components on the dynamics of gameplay, with a specific focus on the role of deception and/or misrepresentation. The examination also encompassed the utilisation of audible communication for the transmission of strategies, as well as the assessment of the necessity of audible communication within the game.

As a last category, the participants emphasised various cognitive aspects related to players' intellectual functioning The discourse revolved around the requisite reading proficiency necessary for comprehending game regulations and directives. The intricacy of the game's state, encompassing decision-making and information processing, was taken into account. The evaluation encompassed memory demands, such as the retention of rules or game states. The analysis focused on the progression of the game, encompassing the seamless transitions between different phases. The study also examined various aspects including the quantity of token combinations, the interplay of rules, the mechanisms for scoring, the level of general knowledge required, and the demands for multitasking.

The themes that have been identified through the focus group discussions offer valuable insights into the measures of inclusivity that are essential for the design of inclusive games. Game designers have the potential to enhance the accessibility and engagement of their creations by taking into account the motor, communication, sensory, and cognitive requirements of a wide array of players. It is of significance to acknowledge that the findings obtained highlight the validation of the accessibility and inclusion conceptual framework formulated by Sousa et al. (2022), as the measures employed can be regarded as indicative of intersectional accessibility. There exist various measures that, despite being assigned to a specific category, may encompass multiple needs, thereby demonstrating the importance of investigating how the personal context and distinctiveness of each player are shaped by the individual and cumulative aspects of their characteristics.

Lying and/or bluffing in analogue GBL can be seen as a paradigmatic example of this intersectional nature, having a significant impact on inclusivity, and intersecting with various categories such as communication, sensory needs, cognitive needs, and general knowledge requirements. Effective communication skills are essential for deceiving opponents or conveying false information convincingly, which can intersect with sensory needs like visual and auditory processing. Visual cues, such as facial expressions or body language, are often used in lying and bluffing, posing challenges for individuals with visual impairments. Similarly, auditory cues like tone of voice or speech patterns play a role, making it difficult for those with hearing impairments to perceive and interpret

them. Cognitive skills like strategic thinking and memory are necessary for successful lying and bluffing, but individuals with cognitive needs may struggle with these aspects. Additionally, leveraging general or specific knowledge is often required, which can be challenging for individuals with lower general knowledge levels. To create inclusive experiences, game designers should consider alternative communication channels, accessible visual or auditory cues, adaptable gameplay options, and diversified knowledge-based requirements. Moreover, the specific case of lying and/or bluffing can also be seen as a matter of emotional accessibility, according to the Meeple centred Design Heuristic Toolkit (Heron et al., 2018). Lying and bluffing in games can also be a matter of emotional accessibility. It involves understanding and interpreting the emotions of other players, regulating one's own emotions, and navigating complex social dynamics. This happens since individuals diagnosed with emotional conditions, such as autism spectrum disorders or social anxiety, may encounter difficulties in engaging in and effectively regulating this particular aspect of gameplay. Therefore, it is important to mention that, by incorporating the concept of emotional accessibility into the process of game design, developers have the ability to construct interactive experiences that facilitate emotional comprehension, management, and inclusive interpersonal interactions, thereby guaranteeing a more comprehensive and gratifying experience for players with varying emotional requirements.

In a broader manner, participants engaged in discussion of diverse aspects of inclusivity, encompassing the identification and resolution of instances of exclusion, the establishment and enforcement of protocols to guarantee inclusivity, the proficient management of teams, and the active promotion of inclusive communication. Furthermore, the significance of language and listening was underscored as crucial elements in the development of inclusive GBL experiences.

The discussions also highlighted the significance of incorporating inclusivity into game design, which involves taking into account factors such as gameplay limitations, integration of educational components, embracing a wide range of perspectives, and determining optimal group sizes. The importance of ensuring that gaming experiences are enjoyable and applicable to real-world situations was also highlighted.

The focus group discussions in this academic paper explored the advantages, difficulties, and considerations associated with analogue GBL in educational environments. The discussions highlighted the benefits of games in enhancing communication, comprehension, and engagement. They also emphasized the importance of evaluating learning outcomes, promoting inclusivity, and designing games deliberately to optimize the effectiveness of GBL. The discussions provided insights into various aspects of GBL, including visualization, teamwork, real-world applications, and the qualities of a good game. The findings also showed that soft skills and specific subjects like project management and information technology can be effectively taught through games. Overall, the discussions offered valuable perspectives on the factors and components that contribute to the success of GBL in educational contexts.

5. Conclusion

The aim of the present study was to explore the understanding and implementation of inclusivity measures in GBL – considering both the existing state of the art and multistakeholder perceptions – while emphasizing the importance of designing accessible and engaging games that cater to a wide range of players' needs and characteristics.

In conclusion, the state of the art in analogue gaming accessibility is still relatively limited in scholarly and professional literature. However, there have been significant advancements in the field, such as the development of frameworks for evaluating the accessibility of board games, like Meeple centred Design (Heron et al., 2018). It is crucial for designers and publishers to adopt these frameworks to promote accessibility and inclusion in board games. While accessibility and inclusion have not been extensively studied in the board game community, there is potential for board games to promote a sense of inclusion in learning processes (Sousa et al., 2023). Analogue games have been found to cultivate soft skills and accommodate individuals with different abilities or characteristics, such as introverts or those with divergent thinking abilities. Empirical research has shown that perceptions of inclusivity measures in GBL vary among educators. Inclusivity needs to be considered from different angles depending on the specific classroom and the challenges faced by students. Flexibility and creativity are essential in addressing inclusivity issues, whether they are related to specific disabilities, cultural differences, or language barriers.

Regarding the perceptions of the different stakeholders, the focus group discussions revealed recurring themes related to the implementation of GBL, including assessment, inclusivity, gameplay restrictions, educational elements, diverse ideas and perspectives, and the connection between game experiences and real-world contexts. The analysis focused on the discussed aspects of inclusivity measures, which allowed for the

identification of relevant measures by different stakeholders in the GBL process. These measures encompassed motor, sensory, and cognitive needs of players. Motor requirements included factors such as dimensions of game components, physical interaction, and the utilization of paper currency, which are important for promoting inclusivity and engaging players with diverse motor abilities. Sensory needs, particularly visual and auditory, were also discussed, emphasizing the importance of optimal visibility, reading proficiency, and audible communication in gameplay. Cognitive aspects, such as reading proficiency, decision-making, memory demands, and multitasking, were also considered.

The identified themes provide valuable insights into the measures of inclusivity that are essential for designing accessible games. Game designers can enhance the accessibility and engagement of their creations by considering the motor, sensory, and cognitive requirements of players. It is important to acknowledge the intersectional nature of accessibility, as different measures may encompass multiple needs. To create inclusive experiences, game designers should consider alternative communication channels, accessible visual or auditory cues, adaptable gameplay options, and diversified knowledge-based requirements.

In addition to inclusivity, discussions also highlighted the importance of addressing instances of exclusion, establishing protocols for inclusivity, managing teams effectively, promoting inclusive communication, and incorporating gameplay limitations, educational components, diverse perspectives, and real-world applicability into game design.

Overall, the findings emphasize the need for inclusive game design that considers the diverse needs and characteristics of players. By incorporating measures of inclusivity, including motor, sensory, cognitive, and emotional accessibility, game designers can create engaging and inclusive experiences that cater to a wide range of players.

5.1 Limitations and Future Directions

The lack of accessibility and inclusivity strategies in analogue games needs to be addressed in the future. Analogue GBL can only become common practice if these needs are taken into account more broadly. Future research on accessibility and methods for achieving it through participation is crucial. There is a need to bridge the gap between industry and academia to better take into account human diversity in analogue game design. It is important to establish a clear vision for the game experience before choosing and adjusting games for educational use. Different students have different preferences as players, so educators should develop an understanding of these preferences and choose a balance of game characteristics that is ideal while still maintaining the game's distinctive vision. The study has limitations and further research using empirical methodologies is needed. The study also has limitations in considering accessibility models and practices from the board game industry. Bridging the gap between industry and academia is necessary to ensure proper implementation of accessibility measures and consideration of human diversity in analogue game design. Educators should have a basic understanding of player profiles and strive to create an inclusive and adaptive learning environment.

Furthermore, it is pertinent to examine the premises pertaining to the conceptual frameworks surrounding the accessibility and inclusivity of analogue games, such as the ones developed by Heron et al (2018) and Sousa et al. (2022). This can be achieved through conducting comprehensive studies that enable a more extensive validation of these assumptions. Such research can also exert influence on policy-makers, urging them to recognise analogue games as a legitimate tool for driving educational transformation.

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A Video Game to Help the Fight Against the Vicious Tapeworm in Africa

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Abstract: The pork tapeworm, *Taenia solium,* is the agent causing the most important parasitic infection worldwide due to its substantial economic and health impacts, disproportionally affecting low-income countries. Health education should form a core component in control efforts and sustain control strategies proposed by the World Health Organization (WHO), such as human treatments. Traditional health education methods have shown to be less effective. Therefore, in the field of tropical medicine, new, engaging ways to teach affected populations are needed. Within the project 'Gaming 4 Health' we developed an educational video game aimed at instructing school-going children in low-income countries about the tapeworm and how to prevent it. Building on the principles of gamified learning and the self-determination theory, we created the educational video game the 'Tapeworm Game'. The game was developed by a multidisciplinary team, following the game design research cycle which included five steps: game planning, game design, prototyping, play testing and evaluation. The 'Tapeworm Game' is a multi-player video game set in an African village. The game's objective is to educate players about the tapeworm and how to prevent the the spread of disease. Players create their own avatar and learn about disease prevention by exploring the village, engaging in minigames and preforming complementary actions, such as handwashing and visiting the toilet. Points are earned by playing the minigames and performing the actions correctly within a given time. The more points a player accumulates, the higher they climb on the leader boards. Rewards are unlocked based on performance and competence and displayed as stars, badges, and avatar customizations. This makes the game exiting and keeps children fully immersed, motivating them to learn, improve and continue playing the video game. With this video game our goal is to educate, raise awareness and advance the control of the pork tapeworm as part of the WHO's 2030 goals for Neglected Tropical Diseases.

Keywords: Serious video games, disease prevention, health education, school-going children, Africa

1. Introduction

Tapeworm infection is treatable but persists in areas with inadequate sanitation and hygiene, lack of meat inspection, free roaming pigs, and where little or no knowledge about the parasite and its consequences is present. Tapeworm infections are particularly recurrent problems in resource-poor areas of Latin America, South and South-East Asia and sub-Saharan Africa. When tapeworm larvae develop in the central nervous system, neurocysticercosis (NCC), the neurological form of the disease, occurs (Del Brutto, 2012). According to the World Health Organisation (WHO) (2021), NCC contributes to 30% of epilepsy cases in areas where the parasite is widespread (Ndimubanzi et al., 2010).

Efforts to control and eliminate the parasite have been made (Gabriël et al., 2020), but long-term interruption of tapeworm transmission has not been achieved yet. One effective way to mitigate the risks and prevent the parasite, is through health education. Health education interventions have been tested in some countries, including Zambia, Tanzania, Kenya, India, and Mexico. The results revealed that knowledge about the tapeworm and its lifecycle increased, leading to a decrease in the number of disease cases (Mwidunda et al., 2015).

Compared to traditional forms of education, game-based learning offers more engaging learning experiences and helps learners take more responsible for their own learning (Abdulmajed et al., 2015).

Research by Hobbs et al. (2018) has shown that the computer-based health education program "The Vicious Worm" which they developed, increased the knowledge of primary school students in Zambia. They also recommended focusing on school going children as they can be health agents and pass the educational messages to their communities.

However, research has also shown, that there is a need for more innovative ways to educate the population about health issues. This should be done in a way that will keep the learners actively engaged rather than allowing them to passively observe (Fogarty, 2019). In this regard, serious games can be powerful tools to

disseminate health messages and educate affected populations. In particular, video games provide extensive player involvement and immersion, and can support health message delivery in an entertaining and engaging format (Perttula et al., 2017).

Within the project 'Gaming 4 Health' we developed an educational video game with the aim of educating school going children in low-income countries about the tapeworm and how to prevent it.

2. Objective

The objective of this study was to develop and test a serious video game for disease prevention in an African context, using the tapeworm as a disease example.

3. Methodology and Results

Building on the theory of gamified learning and the self-determination theory, the educational video game the 'Tapeworm game' was developed. The game was created by a multidisciplinary team, following the game design research cycle by Espinosa-Curiel et al. (2020). The cycle included 5 steps, see Figure 1.

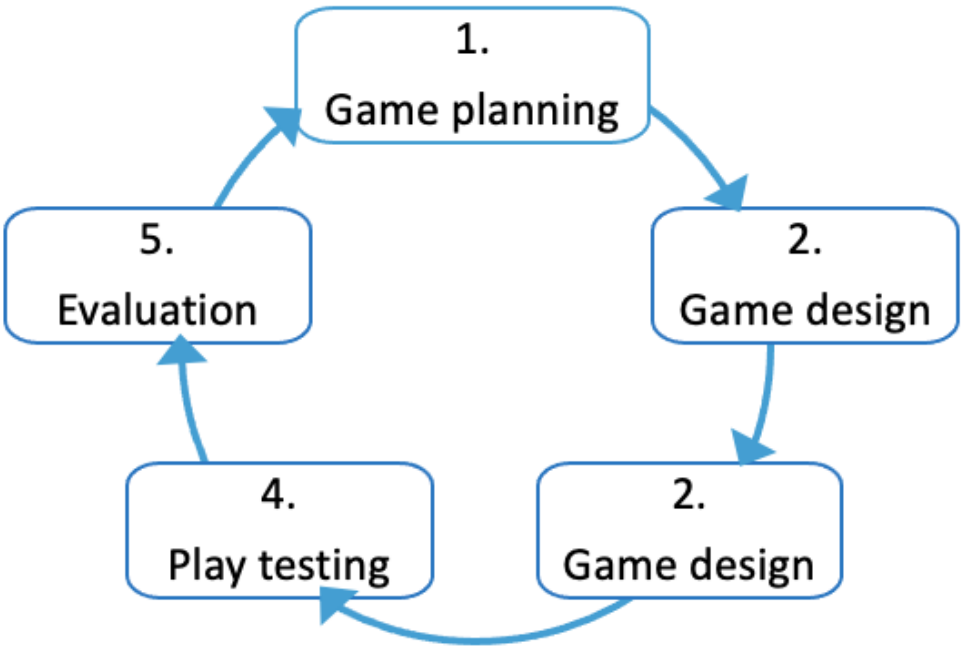

Figure 1. Serious video game design cycle

3.1 Game planning

The overall goal of the game is to educate players about the correct measures to prevent the spread of the disease. In step 1, the multidisciplinary team consisting of a game developer, parasitologists and education scientists convened several meeting to determine the elements that should be included in the serious game and to identify key health messages for disease prevention and behaviour change. Drawing on the self-determination theory of Ryan and Deci (2000), which provides a framework for the study of human motivation, three fundamental needs were considered during the game planning phase and subsequently integrated into the game design. These needs encompassed the need for competence, relatedness and autonomy (Ryan & Deci, 2000). Regarding the key health messages, the emphasis was placed on sanitation and food hygiene which included the importance of handwashing, using proper toile facilities, inspecting and cooking meat thoroughly and confining pigs to prevent infection.

3.2 Game design

In step 2, we implemented feedback loop sessions following an iterative game design approach. Game mechanics and rules were developed based on the outcome of three game planning sessions. The key messages identified earlier were transformed into in-game scenes and adapted to fit the local context.

The video game was designed in a way that players would learn five core messages for disease prevention by engaging in four minigames and performing two repetitive, but complementary behaviour change actions. The

fulfil the need for competence, we provided relevant feedback, such as using badges or stars to indicate the players achievement level (Wong et al., 2020). To create sense of relatedness, we incorporated collaborative learning, allowing players to track the progress of classmates who were also playing the game (Gopinath Bharathi et al., 2016; Wang & Huang, 2021). Lastly, drawing from the work of Bavelier and Green (2019) the game displayed the player's current performance status sand goal achievements, while offering challenges, in-game choices or decision-making opportunities to enhance player autonomy (Bavelier & Green, 2019). This autonomy was furhter supported by allowing the players to create custom avatars and compare themselves with others.

3.3 Prototyping

In step 3, we developed the video game prototype using the Unity video game engine. The "Tapeworm Game" is a multi-player video game set in an African village (Figure 2). When players start the game, they have the opportunity to create their own avatars and learn about disease preventions by exploring the village, engaging in four minigames, and preforming complementary actions. One minigame aims to explain the importance of inspecting meat for larvae, requiring players to remove as many larvae as possible within a given time frame. In the second minigame the emphasis is on cooking. Players must light a fire and cook the meat at the right temperature to prevent human infection. The third minigame uderscores the importance of confining pigs by challenging the players to build a pigsty (Figure 3). Complementary actions in the game include washing hands and visiting the toilet to teach the importance of hygiene and sanitation.

Points are earned by playing the minigames and correctly performing the actions (visiting the latrine and washing hands). The more points a player accumulates, the higher the scores on their leader boards. Rewards are unlocked based on performance and competence, displayed as stars and badges. These rewards and avatar customizations make the game exiting and keep players fully immersed, motivating them to learn, improve and continue playing the video game.

Figure 2. Multi-player video game set in an African village

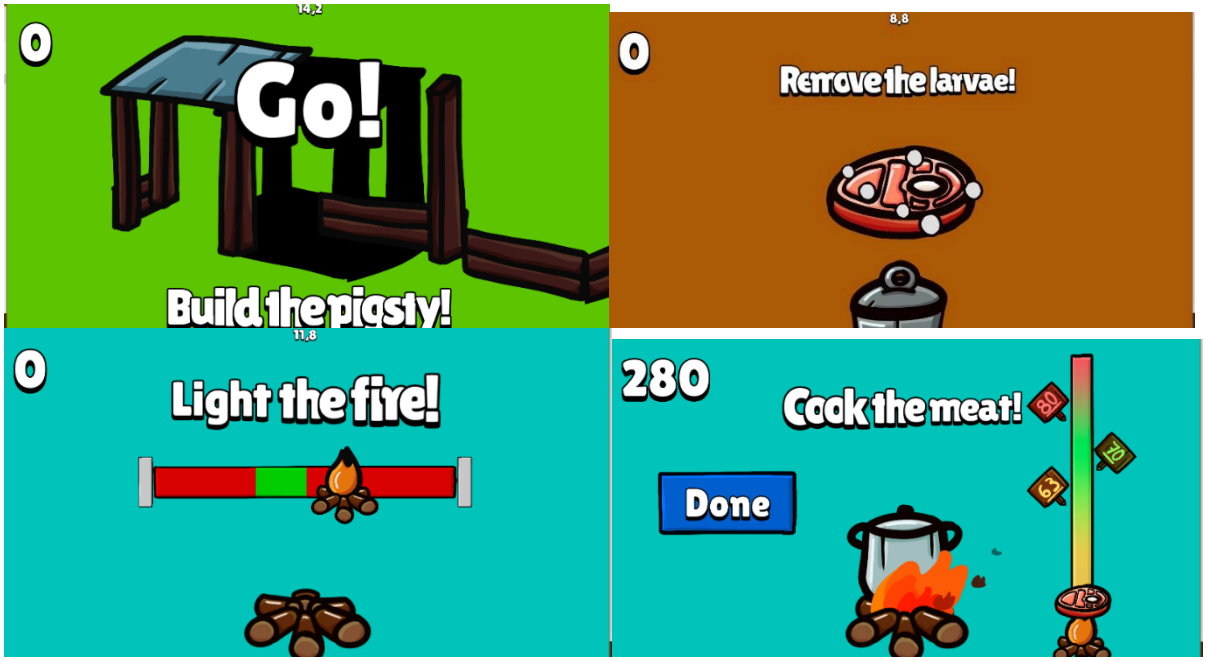

Figure 3. Four minigames: Build the pigsty, remove the larvae, light the fire and cook the meat.

3.4 Play testing

Step 4 involved testing the video game. Due to the Covid-19 pandemic, the pre-post gaming experimental study was conducted in 2022 in three schools in Belgium, instead of in Zambia, as initially planned.

3.4.1 Research questions

The study was guided by two research questions:

Q1. Did the students involved in the experimental condition using game-based learning achieve higher learning performance compared to students in a control condition based on explicit instruction?

Q2. Did the students in the experimental condition using game-based learning achieve higher intrinsic motivation compared to students in a control condition based on explicit instruction?

3.4.2 Study Design

The schools were selected based on opportunity sampling. One class per school was chosen, and atwo-hour workshop was organised, including a total of 60 pupils. Initially, a brief introduction to the workshop was given. Then, baseline knowledge was assessed by administering a pre gaming questionnaire to the entire class. The classroom was subsequently divided randomly into one control and one experimental group. The control group moved to a different classroom and received explicit instruction about the tapeworm through a traditional presentation in Dutch using a PowerPoint presentation given by one of the researchers. The experimental group remained in the same classroom with another researcher and played the video game. After one hour, all participants reconvened in one classroom and completed the post-gaming questionnaire.

To measure learning performance, the pre-post gaming questionnaire was developed as a multiple-choice questionnaire, covering the health educational messages presented in the video game. An example of such a question was “How do you cook your meat to kill the eggs of the pork tapeworm?”. Each question had one correct answer out of four choices.

3.4.3 Data collection and analysis

The data was collected using paper-based pre-gaming and post-gaming questionnaires. Next the data was transcribed in Excel using a coding manual and analysed. A maximum of fourteen points could be earned, with each question being worth one point when answered correctly.

3.4.4 Results

In total 60 children between 10 and 12 years old took part of the study, including 28 females (47%) and 32 males (53%). The control group consisted of 29 participants, including 17 males and 12 females. For the experimental condition included 31 participants, with 15 males and 16 females. Table 2 summarizes the mean and standard deviations for the research variables.

Table 2 Mean and standard deviation of research variables

Variables Learning performance	**Control (n=29)** **M(SD)**	**Experimental (n=31)** **M(SD)**
Pre-test	6.59 (1.35)	5.69 (1.90)
Post-test	8.50 (6.54)	6.65 (1.80)
Intrinsic motivation	5.69 (1.11)	7.86 (1.51)

Figures 4 and 5 display the baseline knowledge of the students in the experimental and controlled conditions. Among the 31 students in the experimental group, 6 achieved a score of ten points. The highest score obtained was 12 points. Notably the scores on the post-test exhibited a wider distribution compared to those of the pre-test. Two students scored 13 and 14 points on the post-test. Additionally, 21 students scored 7 points or higher on the pre-test, while 26 students achieved this on the post-test. In the control group it was evident that the students preformed better on the post-test than on the pre-test, with most students scoring 12 points or higher in the post-test.

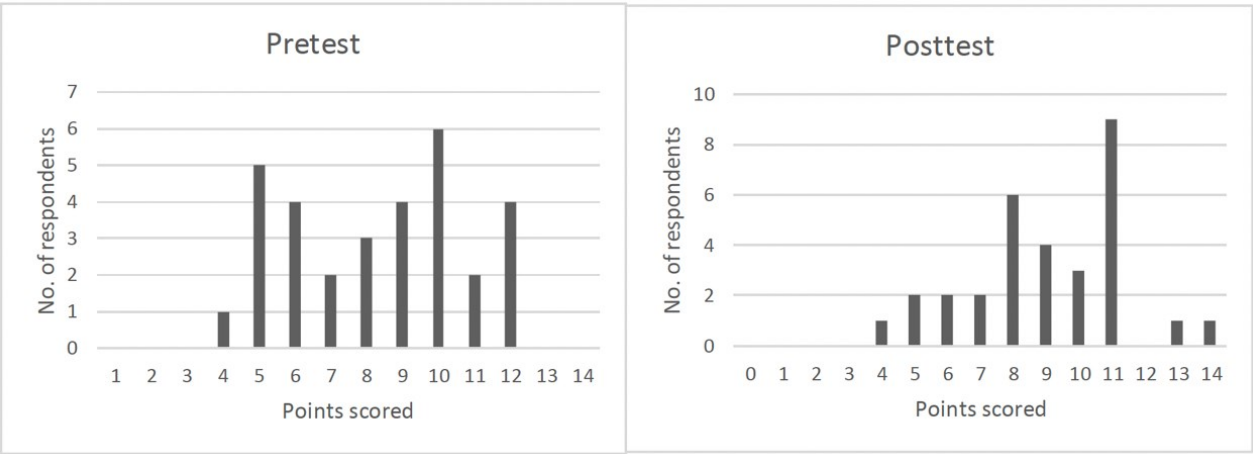

Figure 4. Distribution of pre and post test scores for the experimental group playing the video game.

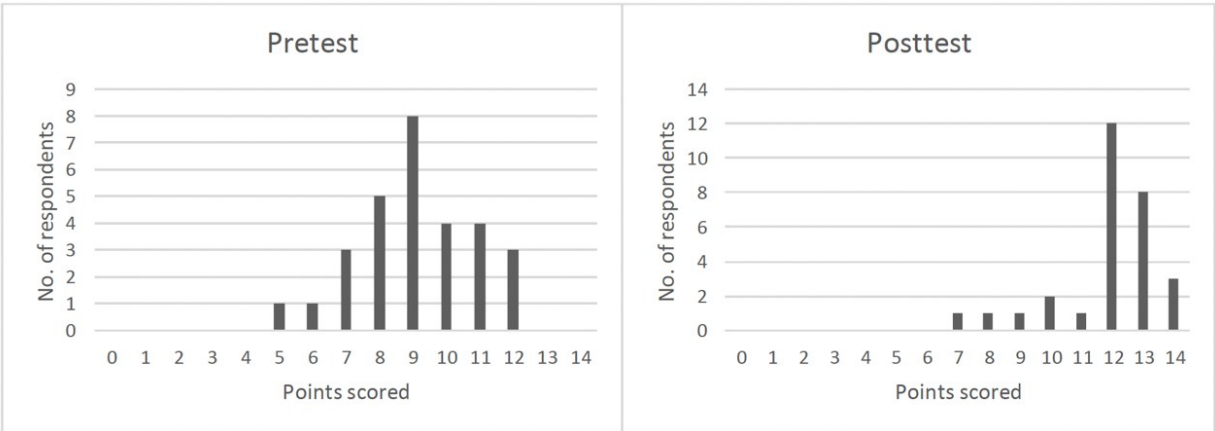

Figure 5. Distribution of pre and post test scores for the control group.

A univariate analysis was conducted to test the impact of condition on learning performance. Statistical analysis revealed that there was a significant difference between both conditions for learning performance $F(1, 58) = 18.33$, $p < 0.005$. Notably, the students in the control condition outperformed the experimental group.

In terms of intrinsic motivation, the results showed a significant interaction between intrinsic motivation and condition, $F(1, 58) = 40.08$, $p < 0.005$. Learning in a gamified condition had a positive effect on the students' intrinsic motivation.

3.5 Evaluation

Step 5 involved the game evaluation by the pupils that participated in the experimental study. Additionally, a group of educational sciences students from the Faculty of Psychology and Educational Sciences of the Ghent University, Belgium, provided additional feedback for improvement.

Subsequently, all the user feedback obtained in step 5 was collected, analysed, and discussed in an additional multidisciplinary session. Changes for improvement were recommended for a new prototype.

For evaluation, the EGameflow questionnaire, which measures enjoyment offered by eLearning was used (Fu et al., 2009). This questionnaire helped in understanding the strengths and weaknesses of the game from the learner's perspective (Fu et al., 2009). To assess user satisfaction with the video game, a questionnaire was developed based on the GUESS questionnaire (Phan et al., 2016). A description of the categories used in the two questionnaires is summarised in Table 3. To accommodate younger children who might have difficulty reading, smiley faces were added to visualise the Likert-scale from one to five in the questionnaires (Yahaya & Abdul Salam, 2008).

Table 3. Questionnaires' categories and content

Category	*Content*	*Category*	*Content*
Concentration	The game grabs my attention	**Usability/Playability**	I think it is easy to learn how to play the game
Goal clarity	I understand the learning goals through the game	**Play Engrossment**	I feel detached from the outside world while playing the game
Feedback	I receive immediate feedback on my actions I receive information on my status, such as score or level		Whenever I stopped playing the game, I cannot wait to start playing it again
Challenge	The game is too difficult The game is too easy My skill gradually improves through the course of overcoming the challenges	**Enjoyment**	I think the game is fun I am likely to recommend this game to others
Autonomy	I can make choices in the game	**Creative Freedom**	I feel my curiosity is stimulated as the result of playing the game I feel I can explore things in the game
Immersion	I forget about time passing while playing the game	**Personal Gratification**	I want to do as well as possible during the game I feel the game constantly motivates me to keep playing
Knowledge Improvement	The game increases my knowledge about prevention methods of the tapeworm I catch the basic ideas of the knowledge taught	**Audio Aesthetics**	I feel the game's audio (e.g. sound effects, music) enhances my gaming experience
		Social connectivity	I can play the game with other players if I choose I enjoy the social interaction within the game
		Visual Aesthetics	I think the game is visually appealing

3.5.1 Video game analysis and assessment from primary school pupils

In total, 31 children (15 males, 16 females) from the experimental group provided feedback on the video game after playing it.

Figure 6 illustrates the responses of the participants on the evaluation questionnaire. The questions "I receive information on my status, such as score or level" and "I understand the learning goals through the game" received the highest scores, with 17 children giving 5 points to both statements. The statement that received the lowest score was "I receive immediate feedback on my actions".

The pupils also responded to a few open-ended questions. When asked about what they liked about the video game, many pupils appreciated the ability to customise their own avatars. -Participants also expressed their enjoyment in the minigames. Furthermore, the aspect of learning through playing a video game was a common positive feedback point. In response to the question: "What did you dislike about the game", children often mentioned the frequent handwashing requirement, which they found less enjoyable and somewhat boring.

Some suggested including visuals of the tapeworm and adding sound to enhance the game.

In the third question, which inquired whether they enjoyed learning through playing, all participants answered "yes". The most common reasons cited were that playing a game is much more enjoyable than attending a traditional lecture.

Lastly, pupils provided some general remarks. One suggestion was to incorporate the possibility of unlocking other worlds or buildings within the game. It was also recommended to include more levels and minigames to prevent boredom after extended play.

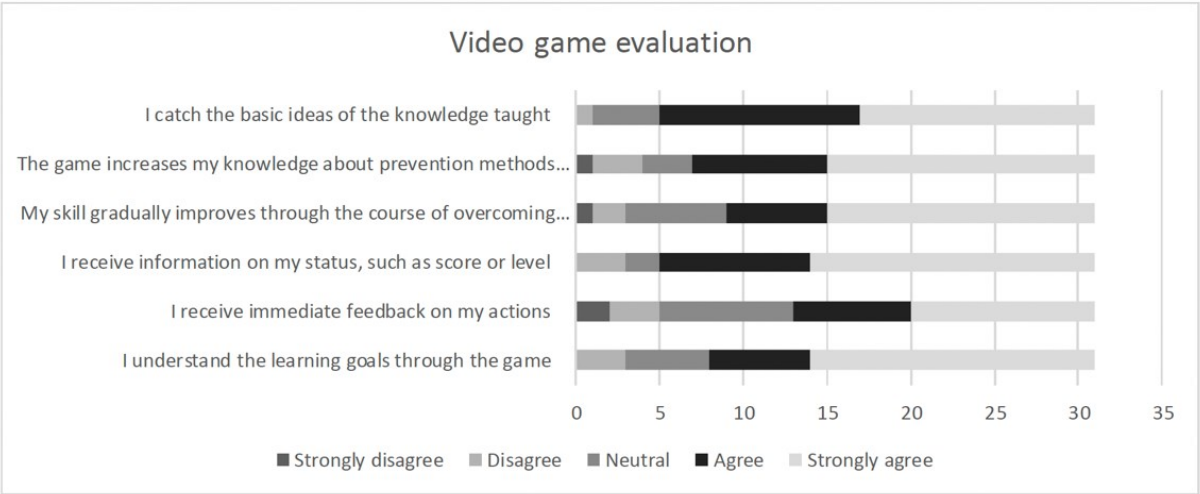

Figure 6. Pupils' responses on the video game evaluation (number of respondands on the x-axis)

3.5.2 Video game analysis and assessment from education science students

Fourteen third-year bachelor students were engaged in the video game analysis and assessment. These students were introduced to the project, asked to play the game, and requested to provide feedback by responding to the Egameflow and GUESS based questionnaires.

The responses of the third-year students are presented in Figure 7 and 8. According to the students, the visuals of the game were appealing, with eight students strongly agreeing, and five students agreeing. The students expressed a desire to perform well while playing the game. Additionally, they concurred with statements such as, "It is easy to learn how to play the game", "I have the feeling I can explore things in the game" and "The game is fun to play". The statement that received the lowest agreement was that the game is too difficult with seven students strongly disagreeing, and five students disagreeing. However, when asked if the game was too easy, sevens students responded neutrally and six students agreed (Figure 7).

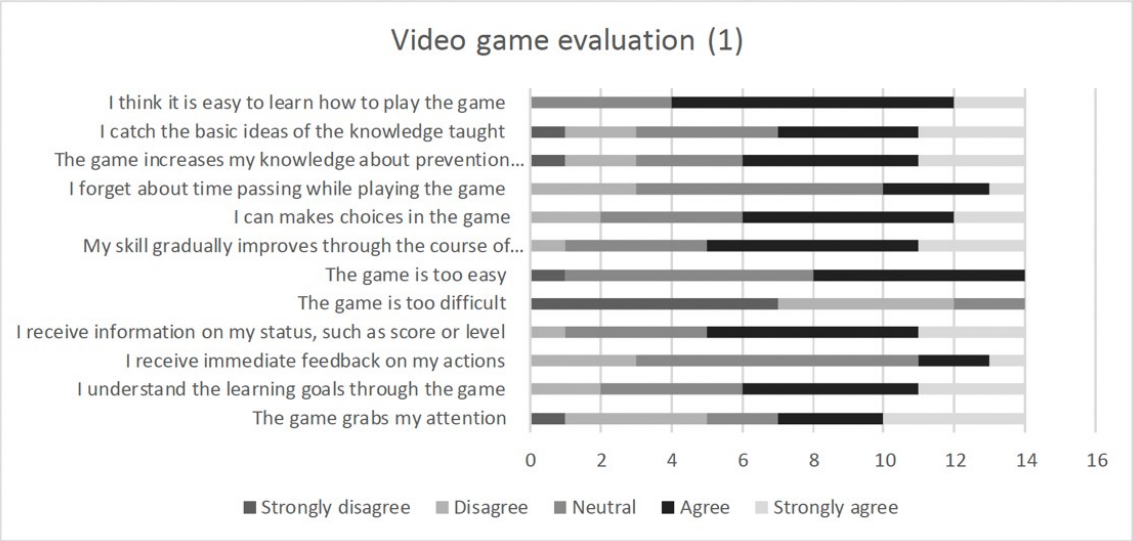

Figure 7. Bachelor students' responses on the video game evaluation (part 1) (number of respondents on the x-axis)

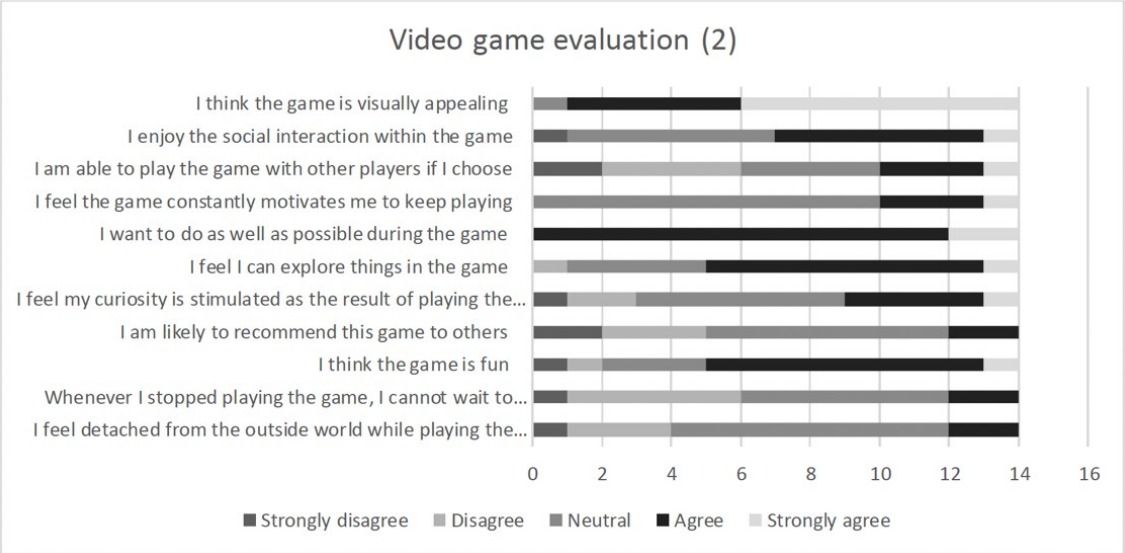

Figure 8. Bachelor students responses on the video game evaluation (part 2) (number of respondents on the x-axis)

The bachelor students also responded to several open-ended questions regarding their likes and dislikes about the video game. The most common positive feedback was related to the customization of avatars, which was seen as a significant asset. Additionally, the layout of the game received appreciation.

On the other hand, the minigames were perceived as becoming boring after a while due to limited variation, especially the activity of handwashing. Some students suggested that the handwashing action could be made more engaging.

When asked about the value of learning through playing, the students noted that the video game served as an accessible tool for children, but lacked a clear theoretical framework.

Finally, the students provided some suggestions for optimizing the game. One student proposed that children should be encouraged to think more about what they need to do to prevent the spread of the tapeworm as the game progresses. Other students recommended that the minigames and scores should be supplemented with explanatory text. For instance, the handwashing activity could include information on the recommended duration, technique, and reasons for proper handwashing.

4. Discussion

In the project 'Gaming 4 Health' an educational video game was developed to educate school going children in low-income countries about the tapeworm and how to prevent it. Due to the Covid-19 pandemic, the game was developed, tested and evaluated by Flemish school going children and third year bachelor students from the Faculty of Psychology and Educational Sciences of the Ghent University in Flanders, Belgium. The study's results revealed that participants who learned through the video game did not achieve higher learning performance scores after playing the video game, compared to the control group. This finding contrasts with the literature, which often highlights game-based technology as an effective tool for teaching children (Baranowski et al., 2016). One possible explanation is that the theoretical framework withing the current version was not clear enough Participants, both children and educational sciences students, expressed difficulties in understanding what the game was trying to teach them and its relevance to tapeworm prevention. To address this, a storyline was added to provide more background and context for the behaviour change actions required in the minigames. However, it is essential to note that the data collected on the impact of game-based learning on learning performance was not context specific. Therefore, a follow up study in Zambia is necessary to draw further conclusions.

Regarding the second research question, the analysis demonstrated that learning in a gamified condition positively affected the intrinsic motivation of the students. Students in the experimental condition exhibited higher intrinsic motivation compared to those in the control condition, which received explicit instruction. This finding aligns with previous studies that have shown serious games to enhance motivation in learning activities and promote better academic achievement among children (Froome et al., 2020; Wong et al., 2020).

The results of the video game evaluation support the idea of serious games as effective health education tools for children. Almost all children expressed a preference for learning through play, emphasising that game-based learning is much more engaging than traditional lectures. Participants provided valuable insights into the strengths and weaknesses of the game and offered suggestions for optimization. However, guidelines on developing serious games, particularly regarding how to support collaborative learning and play, remain limited.

It is important to acknowledge some limitations of the current study. The final version of the game still contained bugs and lacked sound effects, potentially affecting gameplay and user engagement. Additionally, the study recognises the need for a larger sample size to ensure results with sufficient power for generalization. Finally, there is a notable difference in the context of testing the game with children in Flanders compared to rural areas of Zambia, where exposure to video games may be less common.

In future, the optimised game will be tested with a larger sample to ensure that the gamified condition indeed enhances learning performance. Additionally the video game will undergo testing in Zambia to analyse its effects in a different context. A follow-up study could explore the long term effects of the game in Zambia to determine if the newly acquired knowledge about the tapeworm remains prominent and contributes to tapeworm control efforts.

5. Conclusion

In this study, we detailed the process of developing a serious video game for disease prevention in Africa. The results indicate that the developed serious game hold promise as a health education tool for primary children, provided that the necessary improvements are implemented. Nearly all children expressed a preference for learning through play, emphasizing that game-based learning is much more engaging than traditional lectures. However, based on the findings and evaluations, further optimization of the serious game is needed to enhance learning performance. Subsequently, a longitudinal study can be conducted in Zambia to assess the impact of the serious game on controlling -the tapeworm.

In the next phase, the game will undergo testing and evaluation in an African setting with the aim of educating, raising awareness and contributing to the control of the pork tapeworm, aligning with the WHO's 2030 goals for Neglected Tropical Diseases.

Author contributions

Study design & conceptualization: all authors; data curation & analysis: MJ, FE; writing – orginal draft: MJ, CT; writing – review and editing: All authors.

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Classroom Introduction of a Video Game on Italian Grammar

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Abstract: Despite Italian teachers' strong interest in the use of games, especially the digital ones, there are several critical issues due to their lack of familiarity with games/video games thus making games' adoption in teaching complex because teachers have only limited time to prepare and play a game-based learning game. Therefore they feel uncertain about using games in class due to their limited knowledge of digital games and find it difficult to identify appropriate assessments, they also find it difficult to integrate video games effectively and efficiently into their classroom, it is also difficult for them to choose appropriate games for teaching. Additionally the school/administration doesn't assist their effort to support and improve their skills in game-based learning. The learning of the fundamentals of the Italian language and grammar are described and defined by the Italian Ministry of Education within the "National Indications for the 'Italian Language' Curriculum". However, multiple difficulties often make it arduous to learn the basics of the Italian language. The video game "Ross and the Sgrammanebbia" - which can be translated as "Ross and the Un-grammar-Fog" - is a didactic grammar web video game that has a correspondence between the levels and the topics of the textbook as well as giving the teacher a valid help to organise a didactic path studied on the curricular skills. In order to define the useful guidelines for an effective introduction of the game in the classroom, participatory qualitative-quantitative research was prepared on the methods that a small group of teachers put in place to design the training activity with video games. The research focused on: analysis of the educational design skills for the use of games: definition of learning goals, assessment methods and identified teaching strategies; evaluation of the pedagogical activities implemented to facilitate the introduction of games in the classroom; analysis of the roles played by the teacher during all the phases of the training activity - from the design of the training activity to the introduction of the game in the classroom, to evaluation.

Keyword: lower secondary school, Italian grammar, videogame in education, designing teaching activities, lack of game literacy, teacher's roles in the game-based learning

1. Introduction

In recent years, the interest in games within educational processes has grown exponentially. As the Danish researchers Hanghøj and Brund (2011, p 125) pointed out, despite the fact that research on the educational use of game now has a history of over fifty years, it has mostly examined the effects on learning or an attempt has been made to "identify the intrinsic learning potential of particular play projects" (ibid.), focusing mainly on individual projects and classroom experiments in which games have been investigated in students, focusing the research mainly on the teacher-student interaction (e.g. Tzuo et al, 2012) or on teacher's facilitation during the game (Hanghøj and Brund, 2011).

This research focus has in fact neglected to investigate the teacher's pedagogical dimensions, such as the design solutions or teaching strategies that the teacher adopts when teaching through play. These shortcomings would seem to highlight a lack of reflection on the pedagogy of play in educational processes, and the many observations on the importance and potential of play in educational activities were not followed by broader considerations of the teacher's activities, as well as teaching practices and processes before, during and after play, how to design activities supported and enhanced by play, and the roles that students and teachers assume within learning activities (Kangas et al., 2017a).

2. Issues

Play is not sufficient to create the learning environment within the classroom context, but a dynamic relationship between teaching and learning is always necessary and is linked to the playful experience and design competence of the teacher or trainer. The increase in the number of educational activities that use games in their various manifestations has neither led to a massive adoption of the use of games within schools nor, above all, to an increase in teachers' competence in the use of games for teaching: knowledge of a game includes the identification of its technical characteristics, the pedagogical position and the content embedded within a game (Foster et al., 2011).

Research has found that pre-service teachers report that they do not feel adequately prepared to incorporate play within their curriculum (Allsop et al., 2013; Takeuchi and Vaala, 2014); in particular, factors influencing teachers' use of games mainly include their inability to (a) *Analysis of games* - in the absence of a deep familiarity with games, in addition to a low perceived value of the educational opportunities offered by games (Kenny and Gunter, 2011), the teachers' ability to design and implement games is undermined (Egenfeldt-Nielsen, 2004). For the effective inclusion of games in the classroom, researchers emphasise as a prerequisite that the teacher

is competent to play the game he or she wants to use (Baek, 2008; Hirumi, 2010; Ketelhut and Schifter, 2011). (b) *Game integration*: knowledge of the game alone does not automatically make the teacher competent in teaching with games, even when texts on the game are available or the teacher has years of teaching experience (Eastwood and Sadler, 2013; Magnussen, 2007). The aim of game integration is to combine knowledge of game characteristics with teachers' teaching and curricular experience (Ritzhaupt et al., 2010; Rice, 2007). This primarily involves the teacher adopting multiple pedagogical roles to facilitate students to intentionally connect their experiences within the game to those within their curriculum.

Several factors that affect the introduction of play in educational activities have been identified in the international scientific literature. Those that can be ascribed to the teacher are (Hanghøj, 2013): poor/absent game literacy, presence of prejudices about the role and meaning of play in society and culture, difficulties in translating curricular learning goals into playful activity and/or play, difficulty in identifying and selecting the most appropriate game and integrating it effectively and efficiently within the training activity and difficulties in identifying appropriate assessment methods for learning goals and play objectives.

Besides teachers, students, school, family, and territory should be taken into consideration (Andreoletti and Tinterri, 2023), for the purpose of the present article this will not be discussed in detail.

2.1 The teacher's roles

The research by Kangas et al. (2017a) highlights the importance of the teacher's active role in the integration of games intended for learning into teaching: depending on the learning objectives and the game context, the teacher's role varies from leader to facilitator, from organiser and planner of learning activities to guide and tutor during game sessions.

The roles that the teacher assumes during classroom activity are central, not only in connecting game-based learning to the curriculum, but also in connecting the world of play to the real world and in evaluating the processes and outcomes of game-based learning (Kangas, 2010b; Meyer and Sørensen, 2011; Watson et al, 2011). However, the teacher does not always know how to be supportive of students in play (Magnussen, 2007). This means that it is possible for a teacher to hinder or even nullify the learning potential in a game based on roles he or she assumes during the learning activity. These roles require skills that may not be intuitive and that are not normally acquired through training courses or essays on games.

Hanghøj (2013) highlights how the teacher moves among four different roles, taking on the role of instructor, director, guide and evaluator from time to time. These roles are not mutually exclusive: it is normal for a teacher to take on several roles at once and to switch from one to the other quickly.

Player: The teacher assumes this role usually before the start of the lesson. Experimenting with the game before bringing it into the classroom prepares the teacher to understand what roles the students will assume during the activity, to identify any critical issues the students may face and what kinds of support the teacher should put in place to help them.

Instructor: This role concerns the planning and communication of the general objectives of a game scenario in relation to certain learning goals and is an integral part of most teachers' daily practices.

Guide/Observer: The teacher supports or encourages students in their attempts to achieve particular learning objectives during the game activity.

Playmaker/Initiator: Teacher's ability to manage tasks, roles, objectives and dynamics within a particular game scenario seen from the player's point of view.

Referee: The teacher helps the participants to play together and/or facilitate the type of competition.

Character: When the teacher assumes the role of a character within the game or when he or she inserts himself or herself within the narrative expressed by the game.

Discipline Expert/Advisor: The teacher always remains the discipline expert and, during the game activity, can act as an advisor to the players in matters related to the subject of the game.

Evaluator: The teacher's ability to assess the outcomes of the play activity and the students' learning experiences.

Teacher roles should not be understood as ideal types or normative goals for teaching with games; rather, they can be seen as heuristic categories based on the empirical analysis of teachers' game practices.

3. Search

3.1 Participants

In order to analyse the use of video games within the classroom activity, it was decided to identify a small number of classes in which to directly observe how on the one hand the teacher proposes the game as well as linking it to the educational goals, organising and managing the classroom activity, while possibly arranging supplementary activities and evaluating the educational activity; on the other hand, the students are involved in the educational activity integrated with the game, how they play the game, their attitudes towards a video game specifically designed for learning grammar.

So as to define the sample, it was at first decided to adopt a non-probabilistic (Creswell, 2013) reasoned-choice sampling (Ferrarotti, 2006), identifying a suitably selected group of classes in the first year of secondary school, in which the teachers in charge of the Italian course had adopted the textbook combined with the video game. The search for teachers, which took place between January and February 2023, went through a process of dissemination of the project within teachers' organisations, which made it possible to identify 14 teachers, subsequently reduced to 10.

The sample consists of:

- 10 female teachers, who taught Italian in the first classes of secondary school;
- 10 classes involved from 6 different schools, 2 in the urban area of the city of Turin (Piedmont region) and 4 in the urban area of the city of Milan (Lombardy region);
- 2 classes belong to 1 Private School in the city of Milan; the other 8 classes belong to 5 State schools in the cities of Milan and Turin;
- 185 students involved (92 boys and 93 girls) aged between 11 and 12.

3.2 Subject

The subject of this research is "Ross e la Sgrammanebbia", an online video game related to the fundamentals of Italian grammar, produced by Deascuola (a school publishing operator in Italy based in Milan) and developed by Tiny Bull (an Italian video game developer based in Turin). There is a correspondence between the game levels and the topics of the textbook to which it is appended, and it offers the teacher a valuable aid in organising a didactic path designed around curricular skills.

The game is a adventure game and is composed of three main components: a narrative component acts as a link between the minigame and educational activities; a purely game component with skill challenges and hand eye coordination game; a learning component: the use of game language and of game dynamics in interactive learning activities is very limited cause of the lack of knowledge of the teacher's game dynamic.

The game was completed in about 11 months divided as follows: 3 months for conception, 3 months for design and 5 months for implementation and testing.

3.3 Methodology

An integrated qualitative-quantitative research approach was chosen - selecting the most suitable one according to the objectives of the research at different stages of the project (Cresswell and Plano Clark, 2011; Cresswell, 2014) - in order to investigate the ways in which teachers design the training activity integrated with the game, manage the game-integrated teaching activity in the classroom and evaluate the activity as a whole.

Phase 1 - Teacher's relationship with games and video games (second half of March 2023)

The first step, initiated after the identification of teachers between January and February 2023, concerned the analysis of the sample of teachers selected for the project and used a questionnaire with structured and semi-structured questions administered using the Google Form platform (CAWI technique).

Phase 2 - Design of teacher training activities (end of March 2023 - second ten days of April 2023)

The second step aimed at analysing the teachers' level of mastery of educational design using two separate instruments: administration of a questionnaire with structured and semi-structured questions using the Google Form platform (CAWI technique) and delivery of the game-supported training activity design sheet.

Phase 3 - Observation of classroom activity (end of April 2023 - first ten days of May 2023)

The third step, the very heart of the research, focused on how the teacher manages the classroom activity with the aid of the video game "Ross e la Sgrammanebbia", it took place through an ethnographic approach (Corbetta, 2003; Babbie, 2010) given by observing participants during the lesson.

Phase 4 - Analysis of classroom training outcomes (first-second decade of May 2023)

The fourth and final step, in the days immediately following the classroom observation, was structured with a qualitative-quantitative approach, based on a questionnaire and a semi-structured interview administered at two consecutive times: the questionnaire, administered to teachers using the Google Form platform (CAWI technique), aimed to evaluate the training activity carried out; following the administration of the questionnaire, a semi-structured interview lasting approximately 60 minutes was organised, based on the analysis of all the elements collected (questionnaire, design and observation).

3.4 Experimentation

Classroom experimentation was planned over a single lesson lasting between one and two hours and managed through observation. The analysis of the time actually devoted to the game in relation to the time devoted to the entire teaching activity shows how the teachers acted heterogeneously: at one extreme, the game was reserved for a minimal portion of the overall lesson activity (18 minutes out of a total of 85, i.e. 21% of the time) and, at the other extreme, the game took up the entirety of the scheduled time (42 minutes, i.e. 100% of the time).

4. The teacher as mediator of the video game in the classroom between poor game literacy, educational goals, game objectives and pedagogical dimensions

Given the critical issues highlighted, the aim of the research was to understand what the possible obstacles were to the introduction of a video game specifically designed for the teaching and learning of the elements of Italian grammar present in the Curriculum for the first grade of the lower high school and to identify the most effective strategies to facilitate its appropriation by the teacher and its effective introduction within the classroom teaching activity.

This article seeks to provide an initial response to these critical issues by considering the following three aspects.

4.1 Lack of familiarity with the game (game literacy)

The sample of teachers in the research is in line with what is indicated in the literature on Game Literacy (Kenny and Gunter, 2011) as only 3 of them (n=10) use games in their everyday life outside their professional activity. The analysis of the indicated titles highlights 'hobby' games and video games on personal smartphones of the 'casual' genre. 4 teachers indicate that they have had previous experience of introducing games/videogames in the classroom. The analysis of the types of games highlights a "low" and "simplified" use of the game, as the titles indicated can be traced back to behaviourist online solutions (Egenfeldt-Nielsen, 2007) or to knowledge assessment tools "disguised" with gamified mechanics (Kahoot!, Mentimeter etc.).

Research indicates that teachers who make little use of play in their daily lives find it difficult to *perceive the value of the educational opportunities offered by play* and to *benefit from the potential that play can express*. As indicated above, the causes of this low/absent play experience are multiple and, mainly, can be traced back to ideological reasons about the role and meaning of play in society and culture (Hanghøj, 2013). The consequences of the lack of playfulness are most evident when one compares what emerges from the planning produced by the teacher, what is observed during the activity and the evaluation given by the teacher to the activity carried out in the classroom in relation to the possible scenarios that the video game "Ross e la Sgrammanebbia" can take on in the teaching activity (Chart 1).

Without consolidated personal experience of ludic activity and the use of games that are not referable to behaviourist learning models (Gee, 2003; Egenfeldt-Nielsen, 2007; Andreoletti, 2023), with the mere experimentation of the game to be used, the teacher finds it very difficult to identify all the possible scenarios that the game may take on during the teaching activity and will tend to trace the purposes of the game within consolidated and socially shared practices (exercise, socialisation). An analysis of the designs shows that teachers indicate only four possible scenarios: exercise space, socialisation moment, point of view examples and evaluation tool.

The self-assessment carried out at the end of the classroom activity also investigated the types of scenarios attributed to the video game and shows how the teachers rethought the purposes the game served during the lesson. The number of scenarios increased, not only consolidating those previously identified in the design

(socialisation moment, exercise space, assessment tool) but also identifying different purposes closely linked to disciplinary aspects (stimulus for self-reflection, reflection stimulus, content systems).

It was, however, the observational moment in the classroom that highlighted how the teacher managed the game in the classroom by also attributing scenarios not previously identified in the design or considered in the self-assessment phase. The observation identified the use of scenarios more related to disciplinary aspects (content systems, exercise space, reflection stimulus, evaluation tool) and not only to motivational/social aspects (socialisation moment).

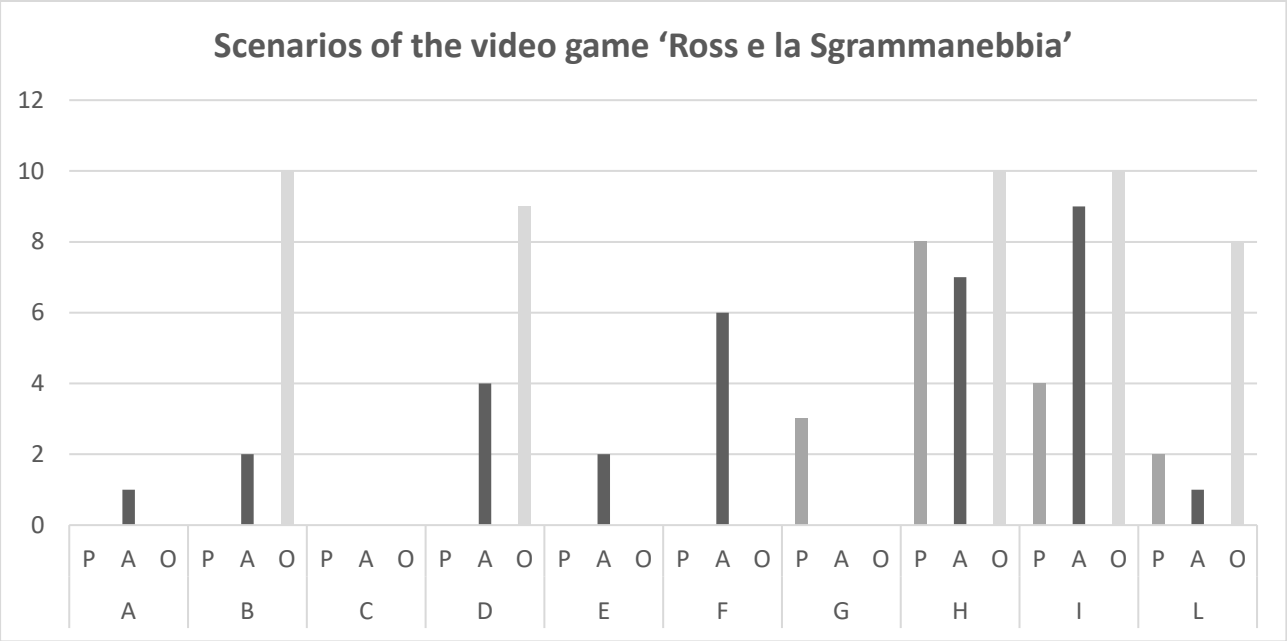

Chart 1: Comparison of the video game scenarios between Teacher's planning (P), Evaluation of the activity by the teacher (A), External observation of the implemented activity (O).

Scenario legend: (A) Self-expression, (B) Content systems, (C) Simulation and manipulation of systems, (D) Stimulus for reflection, (E) Introduction (gateway) of technologies, (F) Stimulus for self-reflection, (G) Examples of viewpoints, (H) Exercise space, (I) Socialisation moment, (L) Evaluation tool.

4.2 Difficulties in translating learning goals with playful objectives in the game

The reading shows that the teacher's lack of practice with play and playfulness both on a personal and professional level does not facilitate the definition of disciplinary goals in relation to playful objectives and vice versa, makes it difficult to define the evaluation methods for educational goals and playful objectives and limits playful activity to the motivational dimension, a mere exercise of content, a moment of socialisation.

In relation to this aspect, it emerged that 9 teachers only attribute cross-curricular functions to play: they mainly point to motivational aspects for the effectiveness of play in learning and the achievement of curricular goals, without however providing any scientific basis to justify their convictions. In line with this aspect, the three main purposes for which games/video games should be introduced in the classroom identified by teachers are motivational (fostering interest in the subject), social (learning together with others) and exercise (consolidating content already learned through repetition). This aspect becomes more evident when the teacher indicates the possible goals of the activity - it emerged that they would use the game/videogame mainly to achieve transversal competences (8 teachers "Personal, social and learning to learn competence", 5 "Functional literacy competence" and 5 "Digital competence"), while only 5 teachers identify the goals in the National Indications for the "Italian language" curriculum.

From the questionnaire proposed prior to the activity, it appears that the most critical issues lie in specific stages of the activity design.

The solutions adopted for linking the disciplinary goals to the objectives of the game: 3 teachers explicitly state that they do not know how to do it, 2 teachers indicate the motivational and social aspects as a solution for the linking, 2 teachers propose vague and generic ways and only 2 indicate ways of linking the narrative and content

aspects of the game to the educational goals. In the questionnaire proposed after the activity in which the game was presented, only one teacher highlights this aspect as critical.

The ways of assessing the outcomes of the video game action within the training activity: 3 teachers express the fact that they do not know how to do it, 1 teacher indicates a generic solution without going into detail on the methods, 3 use self-assessment grids for the students and the teacher's observation of their attitude, 2 teachers indicate specific ways of assessing (written verification and creation of a product on the activity's contents). This critical issue is present to the teachers and is indicated by 50% of the sample in the questionnaire following the activity.

An analysis of the teacher-produced plans, carried out by means of an evaluation grid (scale from 0=absent to 5=well described) relating to the description and evaluation of the disciplinary goals, play objectives, products, and activity phases, shows that (Chart 2).

1. Teachers were generally able to define and evaluate the "classical" aspects of teaching:

- good/very good (Q_3 =4) description of the training aims;
- good/very good (Q_3 =4) description of disciplinary goals and objectives;
- good/very good (Q_3 =4) definition of activity phases;
- discrete/good (Q_1 =3; Q_3 =4.5) definition of assessment methods for disciplinary goals and objectives;

2. the sample showed difficulties when it came to defining game-related aspects:

- low/optimal (Min.=2; Q_1 =2.75; Q_3 =5) description of the play objectives;
- absent/discrete (Q_1 =0; μe=2; Q_3 =3) definition of playful goal evaluation instruments;

3. the sample was very heterogeneous when it came to indicating the products of the training activity:

- absent/good (Q_1 =0; μe=3.5; Q_3 =4) in the indication of the products of the activity;
- absent/optimal (Q_1 =0; μe=4; Q_3 =5) in indicating how the products of the activity are evaluated.

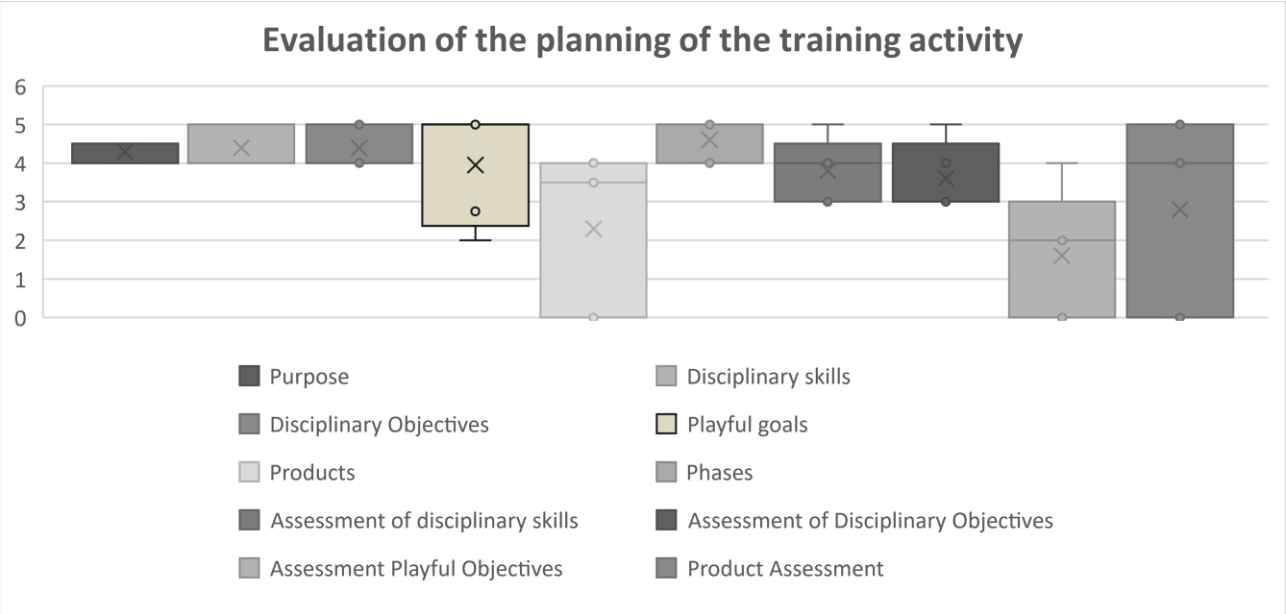

Chart 2 - Evaluation of the training activity design sheet

The teachers themselves are aware of their shortcomings, as 5 teachers indicate as their main critical issue the lack of competence in the use of games in general and 4 the lack of knowledge of games/video-games appropriate to the teaching activity. One of the possible reasons is indicated by 4 teachers as the lack of appropriate technology for the use of video games. From the analysis of the answers given, it can be seen that no teacher indicated Difficulty in introducing games/videogames within the curriculum and Difficulty in assessing game objectives as possible criticalities.

4.3 Reduced focus on appropriate pedagogical models

A further consequence of the teacher's lack of experience with play and play does not make it easy for the teacher to define the possible roles that the teacher can assume during the course of the educational action in order to facilitate the students in linking the playful experiences to the educational objectives of the discipline.

As with the previous two points, the comparison of what emerges from the teacher's evaluation of the activity in the classroom with what is observed during the activity in relation to the possible roles (Chart 3), shows how the lack of playful experience also affects the teacher's ability to identify the roles he or she can take on during the training activity (Hanghøj, 2013; Andreoletti and Tinterri, 2023).

The self-assessment shows that all teachers see themselves as Guide/Observer, a role in which the teacher "supports or encourages students in their attempts to achieve particular learning objectives during the play activity" (Tzuo et al, 2012; Barab et al, 2012; Andreoletti and Tinterri, 2023) and only a minority see themselves in process-related (Director/Author/Initiator, Player, Referee) or task-related roles (Discipline Expert/Advisor, Instructor, Evaluator).

Observation, however, shows a different scenario: the emergence of a teacher who not only manages and organises the training activity (Instructor), but also 'slips' between the different roles during the use of the game in the classroom (Guide/Observer, Discipline Expert/Consultant, Evaluator, Referee, Director/Author/Initiator, Game Character), alternating between those related to the task and those related to the process.

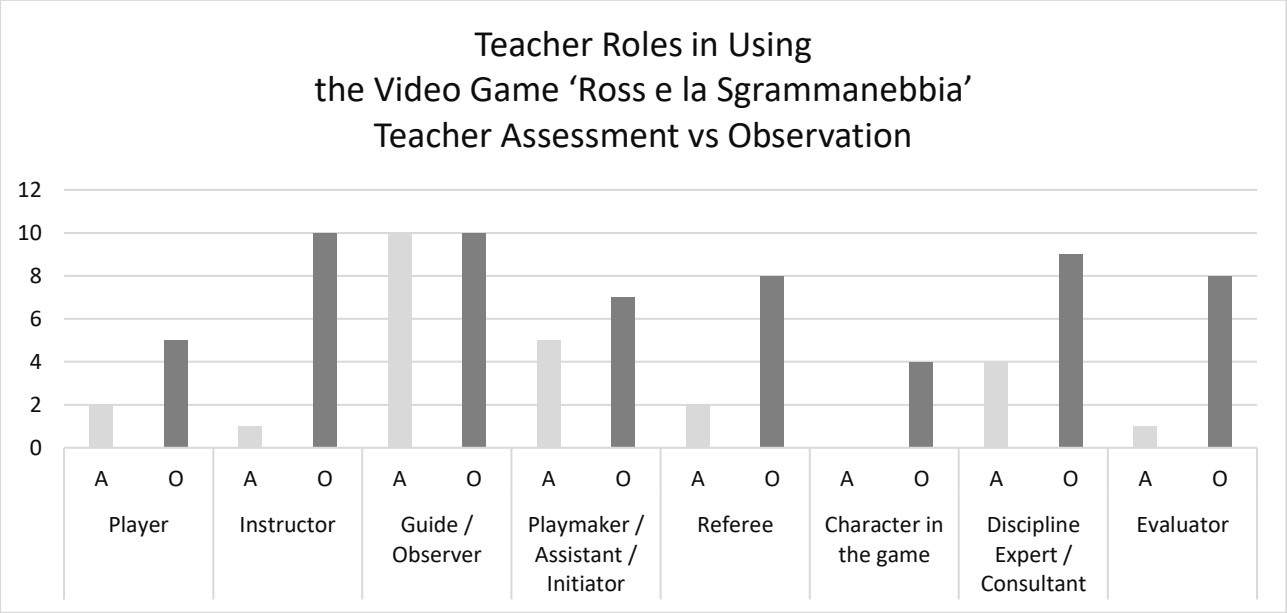

Chart 3: Comparison of the roles assumed by the teacher during the training activity between Teacher evaluation of the activity implemented (A) and External observation of the activity implemented (O)

As Hanghøj (2013) points out, teachers - during a teaching activity in which play is present - take on different levels of participation, moving between being active/interventionist and being passive/observer. As the Danish researcher himself points out, the choice to remain "on the side-lines of the activity" is not always due to unfamiliarity with the game, but is dictated by a conscious pedagogical choice, as it would be wrong for them to interrupt the students' experience of immersion in the game.

5. Conclusion

The use of games in Italian schools and educational contexts is still very limited (Allsop and Jessel, 2015; Loperfido et al. 2019) and directed towards a function of pure entertainment or exercise (Nicholson, 2011) rather than as a real learning environment. The reasons for this discrepancy are, at least in part, due to scepticism regarding the effectiveness of video games in promoting learning. Many teachers seem to be stuck in a "transition phase", as the interest in a resource, which at least on paper is extremely effective, hardly translates into adequate learning episodes when moving around the classroom, due to the virtual lack of personal experience of the teacher's gaming culture, from the very limited, if not absent, training practice with games. Teachers report that they do not feel adequately prepared to include games in the curriculum (Allsop et al., 2013; Takeuchi & Vaala, 2014), as they find it difficult to identify games that align with learning objectives (Molin,

2017) and due to indications on operating methods found online or obtained through training courses that are often unsuitable and qualitatively questionable.

Starting from these considerations and at the request of the teachers interviewed in the final phase of the research, some possible operational trajectories were identified to facilitate the introduction of the game into teaching practices and at the same time work on the main critical issues.

The first viable solution involves the preparation of laboratory-style training activities in which the teacher can be accompanied in the design of training courses in which the mechanisms with which to translate and align disciplinary goals with the objectives of the game and vice versa are understood and, at the same time, actively manipulate the games, hypothesise training paths in which they can be introduced, and directly discuss the experiences implemented with other teachers.

A second solution involves the presentations of games, also via the web, in which other teachers, game-based learning experts and researchers show the different possibilities with which the game can be introduced within the training activity.

As it can be well understood, it is necessary to identify a systemic strategy, which involves all the main actors of the Italian school system in a synergistic and systematic common action, starting from the Ministry of Education first and foremost through all the entities connected to staff training incoming teacher (university training courses for teachers) and in service (trade unions, trade organisations, training agencies, publishers of textbooks and school services and schools). The common objective is to train a competent teacher who knows how to plan training interventions aimed at learning curricular goals with the help of games and video games.

Besides these we cannot fail to consider the first ever educational agency: the family. Initiatives at a local and national level to communicate what the role of school is today, what it means to learn and what to teach and what the role of play as a resource for learning can and should be.

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