Proceedings of the 16th European Conference on Games Based Learning

A Virtual Conference hosted by Lusófona University Lisbon, Portuga

6-7 October 2022



Edited by
Conceição Costa, Filipe Luz
and Nuno Fachada

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Proceedings of the
16th European Conference on
Games Based Learning

ECGBL 2022

Hosted By

Lusófona University
Lisbon, Portugal

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ECGBL Preface

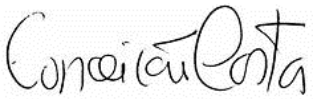
These proceedings represent the work of contributors to the 16TH European Conference on Games Based Learning (ECGBL 2022), hosted by Lusófona University, Lisbon, Portugal on 6-7 October 2022. The Conference Chair is Conceição Costa, and the Programme Chairs are Filipe Luz and Nuno Fachada, all from Lusófona University.

ECGBL is now a well-established event on the academic research calendar and now in its 16th 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, from game design to differences and benefits of both digital and board games and augmented reality as literacy tools and pedagogies of learning, wellbeing and gender in gaming are also addressed in ECGBL2022.

The opening keynote presentation is given by Petros Lameras, Coventry University, UK, on the topic of *Designing Serious Games through Research: A Relational Perspective.* The second day of the conference will open with an address by Patrícia Gouveia, Lisbon University Fine Arts Faculty [Faculdade de Belas-Artes da Universidade de Lisboa, ITI/LARSyS FBAUL], will talk about *Eco gaming: How feminism and play are key to changing the world*.

With an initial submission of 168 abstracts, after the double blind, peer review process there are 85 Academic research papers, 5 PhD research papers, Masters Research papers and 3 work-in-progress papers published in these Conference Proceedings. These papers represent research from Australia, Austria, Belgium, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, India, Indonesia, Iran, Ireland, Italy, Mexico, Norway, Portugal, Slovakia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, The Netherlands, UK, USA and Vietnam.

We hope you enjoy the conference



by Lusófona University
Lisbon, Portugal
October, 2022

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Biographies

Conference and Programme Chairs



Conceição Costa is an Associate Professor at Lusófona University and Principal Researcher at the Centre for Research in Applied Communication, Culture, and New Technologies (CICANT) in Lisbon, Portugal. She is a PhD in Communication Sciences - Media Studies from FCSH-NOVA University. She has been conducting research and publishing on game-based learning approaches in school context as well children game creation and its impact in multiple literacies. Currently, she is the Principal Investigator of GBL4deaf - Game-based learning for deaf students, funded by FCT and LISBOA2020 (2019-2022) and ASDdigital - Distance learning training for secondary education teachers: using visual thinking as a method to teach digital skills to students with Autism Spectrum Disorder (ASD), funded by ERASMUS+ (2021-2023).



Filipe Costa Luz is a PhD in Communication Sciences - Media Arts Studies (FCSH-NOVA University), coordinates Videogames MSc, Ba and is vice-chair of Communication Design Ba at Lusófona University. He lectures digital post-production for film, television, games and animation, developing research activities in projects of communication science, Design and media arts, with the special focus on Culture and Creativity Industries, and Cultural Heritage. His work integrating media technologies at Hei-Lab (http://www.hei-lab.ulusofona.pt) and MovLab (http://www.movlab.ulusofona.pt) it's demonstrative of the relevant experience in cross-media projects that evolve him in academic or professional work for the entertainment, design or communication area.



Nuno Fachada is an Assistant Professor at Lusófona University and a researcher at the Cognitive and People-centric Computing Laboratories (COPELABS). He is currently teaching Programming and Artificial Intelligence (AI) at the Videogames BA, and Research Software at the Doctorate in Computing - New Media and Pervasive Systems. Nuno's main research interests lie in Artificial Intelligence (AI), Modeling and Simulation, and Computer Science Education. He completed his degree in Electrical and Computer Engineering from Instituto Superior Técnico / Lisbon (IST) in 2005, and went on to pursue a master degree in the same institute. During this period (2006-2008), Nuno was a teaching assistant at IST, lecturing subjects such as Programming, Digital Systems and Computer Architectures. He successfully defended his PhD thesis in 2016 (IST), and after a year as a postdoc, moved to his current position at Lusófona University/COPELABS.

Keynote Speakers



Patrícia Gouveia is Associate Professor at Lisbon University Fine Arts Faculty [Faculdade de Belas-Artes da Universidade de Lisboa, FBAUL] and an integrated member of ITI – Interactive Technologies Institute / LARSyS, Laboratory for Robotics and Engineering Systems, IST. Co-curator of the *Playmode* exhibition (MAAT 2016-2019). Works in Multimedia Arts and Design since the nineties. Her research focuses on playable media, interactive fiction, and digital arts as a place of convergence between cinema, music, games, arts, and design. More information here: https://fbaul.academia.edu/PatriciaGouveia/CurriculumVitae.



Petros Lameras is an Assistant Professor at the School of Computing, Electronics and Mathematics and a Senior Researcher at the Centre of Post-Digital Cultures at Coventry University, UK. His research interests span the areas of games science research in general and within the research strand of investigating how learning and teaching in

Science Technology, Engineering and Mathematics (STEM) may be enhanced with the use of games. He has worked as a researcher in European and National Research and Innovation projects exploring the use of technology in learning as well as the integration of games and digital content for developing authentic and meaningful learning experiences. Petros has been awarded prestigious research awards for carrying out research on serious games design (SRHE) and on investigating the use of artificial intelligence in education (British Academy).

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.



Fábio Dias (he/him) has a Bachelor's Degree in Psychological Sciences from ISPA-IU and a Master's Degree in Cybertherapy and Neurocognitive Rehabilitation from Lusófona University. Currently enrolled as a PhD student in Clinical Psychology at Lusófona. Fábio is also a Game Developer and Project Manager at Human-Environment Interaction Laboratory (HEI-Lab), where he integrates a multidisciplinary team of researchers to further boost scientific knowledge in the field of cyberpsychology and to deploy technical solutions for field practitioners.



Ronald Dyer is currently EMBA-Director & Senior University Teacher in the department of Executive & Professional Education at SUMS with over 20 years of project management experience across financial service, education, agriculture and energy focused organizational transformation initiatives. His research focuses on serious games, gamification and play with a specific interest in the use of these tools for improved risk-based thinking practices within projects as well as strong interest in artificial intelligence, theories of play for pedagogical innovation and ideation to support general learner improvement & retention.



Ana Rita Farias completed her PhD in Psychology in December 2013 from ISCTE-Instituto Universitário de Lisboa (ISCTE-IUL). Currently, she is an Auxiliary Researcher and Invited Assistant Professor at Hei-Lab: Digital Human-Environment Interaction Lab. During her career, Professor Farias has held research positions and visited as a guest researcher both in psychology and in business and economics departments. She began her research career studying social psychology – multimodal perception and situated approach to human cognition. Over the last few years, she has pivoted her research agenda from pure Psychology to Behavioural Economics.



Micaela Fonseca holds a PhD in Physics. Micaela is Principal Researcher at HEI-Lab (Digital Human-Environment Interaction Lab) and assistant Professor at the ECATI, Lusófona University. Micaela has been engaged in several VR-based simulation projects, she is co-founder of VR4NeuroPain and Games for Good. She has published several scientific papers in ehealth and serious games.

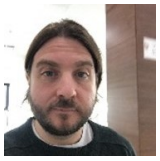


Panagiotis Fotaris is Principal Lecturer and Course Leader for Digital Games Development at the University of Brighton, UK. He is Senior Fellow of the Higher Education Academy and has previously held positions at King's College London, University of East London, University of West London, Abertay University, 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.



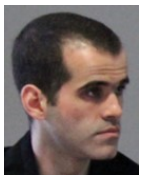
Phil Lopes is an integrated researcher with HEI-Lab and an Auxiliary Professor at Lusófona University (Portugal), and is involved in the development of virtual environments for therapeutic and research purposes. Phil's research interests are human biofeedback data and virtual environments in the fields of Digital Game AI, Affective Computing, Neuroscience and Game Design.



Dominic Mahon is a research fellow at Coventry University in the UK. His research interests lie in the development of competencies, capabilities and resilience through playful approaches to learning. He has worked at universities in the UK Vietnam, Turkey and Kazakhstan over a teaching career of over 20 years.



Nour El Mawas is an Associate Professor in Educational Sciences at Université de Lille and CIREL Laboratory (Trigoneteam). Her research interests are in the Technology Enhanced Learning (TEL) Field, she works on various application fields like crisis management, clinic reasoning, sustainable development, STEM and Computational Thinking. Since 2019, she has supervised two PhDs on modelling and predicting the learning optimal experience in TEL and co-designing serious games by nursing students. She also worked on the design and the evaluation of AutoThinking, a Computational Thinking educational game.



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Jorge Oceja is a teacher, ed. psychologist and M.A in instructional design by California State University (Fulbright Scholarship). In 2017 he obtained his PhD with the thesis "Design of Game Experiences to Promote Civic Competence". In this process he completed academic residencies at the Engagement Lab at Universidade do Minho, the Center for Applied Game Research at Aalborg University in Copenhagen, and the Gamification Lab at Leuphana University in Luneburg. He has taught in Elementary and Secondary in Spain, UK and USA and he is an Associated Professor and researcher at University of Cantabria.



Helena Pereira is a Clinical Psychologist and trainer, she coordinates the course "Games as educational tools" at the IPLUSO's School of Education. In the last years, she has been involved in several national and international projects that use board games applied to serious contexts, and has organized and facilitated training courses for teachers and other professionals that intervene in the educational, social and cultural areas. She believes games can be an incredible tool for working with individuals or groups and tries to spread their potential. She is interested in using board games to promote mental health, inclusion, and educational board game design.



Carla Sousa (she/her) has a Bachelor's Degree in Psychology, a Master's Degree in Clinical and Health Psychology, and a Post-graduate degree in Applied Neuropsychology from Lusófona University. She is a PhD student in Communication Sciences and part of the Centre for Research CICANT. Carla published several papers as

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Author Biographies

Daisy Abbott is an interdisciplinary researcher based in the School of Simulation and Visualisation at Glasgow School of Art. She specialises in serious games and game-based learning, in particular, games for developing research skills or critical thinking. She has developed workflows for co-design of serious games with teachers, schoolchildren, and professionals.

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Sissy Barakari, is an Electrical and Computer Engineer (NTUA), MA in Digital Design and Interactive Applications (Middlesex University), a new-media artist and a cello player. She is finishing her

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Byron Bunt is a senior lecturer in the Faculty of Education of the North-West University and is part of the research unit Self-Directed Learning. He is the subject leader for History Education. His research niche encompasses cognitive education, as well as game-based learning, specifically focusing on developing students' creative and critical thinking via gamification approaches.

Lance Bunt is a lecturer from South Africa. He received his Communications degree from NWU in 2013, an Honours degree in Communication & Media studies in 2014, and a Master of Science degree in Computer Science & Information Sciences in 2020. His research areas include game-based learning, design thinking, serious games, and learning design, among other topics.

Gavin Baxter is a lecturer in Computer Games Development at the 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.

Luca Botturi holds a PhD in Communication sciences from the University of Lugano. He worked in field and research projects in educational technologies in Switzerland, Italy, Canada, Spain and the United States of America. He is currently Professor in Media in education at the Scuola universitaria professionale della Svizzera italiana in Locarno.

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Mike Coffey is a senior lecturer in environmental analytical chemistry. He has published a free-to-use educational board game ("Green Chemistry"), has helped students at NTU design a number of other board- and card-game GBL resources, and is co-chair of the university GBL group.

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Mike Cosgrave lectures on the BA in Digital Humanities & IT and the MA program in Digital Humanities, and the online MA in Digital Cultures at University College Cork.

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Bojan Crnković is employed as an associate professor at the Faculty of Mathematics, University of Rijeka. His scientific interest is in the field of applied mathematics. He is the author of numerous lectures and workshops aimed at the popularisation of mathematics and has participated in the design and organization of several popularization projects and activities.

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Marta Ferreira Dias has a PhD in Economics from the University of Warwick, UK. She is an Assistant Professor in the University of Aveiro. She lectures under graduated and graduated courses, Presently, she is an integrated member of the research unit on Governance, Competitiveness and Public Policies (GOVCOPP). She is a member of research teams of the University of Aveiro participating in several European sponsored projects.

Roberto Di Paolo is a Post-Doc in Economics at IMT School for Advanced Studies Lucca (Italy). His research focuses on Experimental and Behavioral Economics, especially on applying experimental methodologies to study the effectiveness of Game-based educational programs and Games for Social Changes. He is also an ordinary member of the Game Science Research Center.

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Kelly Donovan is currently a Lecturer of English for Academic Purposes at NYU Shanghai teaching: "The Science of Friendship" and "The Final Boss: Defeating Social Issues in Gaming." She was an English Language Fellow with the U.S. Department of State (2018-2020). She received her MA in TESOL from the Middlebury Institute of International Studies (2017).

Francis Dubé is a Full Professor in Instrumental Pedagogy at Laval University. His research interests are Music Game-Based learning, Music Engagement, and Creativity. His research is subsidized by the FRQ-SC, SSHRC, Global Affairs, and CFI. He is the director of the University of Youth Music Play(ers) (UJM).

Michael Dumin holds a PhD research position at KU Leuven, Belgium. He graduated with a Master's degree in Chemistry at the University of Regensburg in Germany and has experience in school tutoring. His main research interests comprise early interest development in chemistry and other natural sciences as well as child-oriented gamification of chemical concepts.

Stine Ejsing-Duun is associate professor in technology, design, and learning at Aalborg University, where she Co-Directs the Center for Applied Game Research (CEAGAR). She explores how playful, digital, and tangible design processes can be used as forms of inquiry promoting creativity, critical thinking, and engagement.

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She is currently a teacher in natural sciences at DFA (SUPSI), a scientific collaborator and an assistant for the course in digital technologies and media.

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

Panagiotis Fotaris is Principal Lecturer at the University of Brighton. He demonstrates a deep understanding of the pedagogical, social, and cultural issues affecting the adoption of new learning technologies. His research interests focus on the pedagogic potential of escape rooms, videogames, and virtual/augmented environments in the context of higher education.

Hugo Kenji Fukumura Pérez. Student of Industrial and Systems Engineering, member of the Innovation and Educational Research Group of the School of Engineering and Sciences of the Central South zone. Interested in educational innovation in order to make changes in the teaching and learning of future generations, to implement technology in the educational system and enhance the knowledge imparted.

Sonja Gabriel works as a professor for media literacy at University Teacher College Vienna/Krems (Austria). Her primary focus of research is on digital game-based learning and using serious games and gamification for teaching different subjects at school and university as well as evaluation of various projects for learning with games and game-design approaches.

Dr. Garay teaches at the City University of New York. He is dedicated to improve the academic experience of students utilizing videogames as tools to boost engagement and understanding of chemistry. He realized that mathematics became the gatekeeper for students to choose STEM careers. If math trouble goes away, interest for STEM subjects must increase. "

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Stefan Göbel holds a PhD in computer science from TU Darmstadt and has longterm experience in Graphic Information Systems, Interactive Digital Storytelling, Edutainment applications and Serious Games. Dr. Göbel is academic councilor and lecturer at TU Darmstadt and heading the Serious Games research group.

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Alvin Kwan obtained his PhD in Computer Science from the University of Essex in 1997 and has taught IT-related courses at the Faculty of Education, the University of Hong Kong since 2001. His key research interests are game-based learning, information management, ICT in education, learning and teaching of technology subjects, and computational intelligence.

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Christoph Lürig is a professor of game programming at the university of applied science in Trier. He holds a Ph.D. in computer science and is a former game programmer with credits including AuqaNox, Splinter Cell, and Army of two 40th day. His research interest covers serious games, simulation, extended reality, and reinforcement learning.

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Astrid Marin is a PhD student in music education at Laval University (Quebec, Canada). Her doctoral project focuses on documenting a learning activity based on the co-creation of music learning games with young students. More precisely, her project aims to describe how this activity calls upon students' creativity and engagement towards this type of activity.

Melinda Mathe is a doctoral candidate at the Department of Computer and Systems Sciences at Stockholm University, Stockholm, Sweden. She has an MSc in International and Comparative Education and also a background in Information Technology for Learning. Her research focuses on the use of digital games and simulations in education.

Bruce M. McLaren is a Research Professor at Carnegie Mellon University and past President of the International Artificial Intelligence in Education Society (2017-2019). McLaren does research that explores how students can learn with games and intelligent tutoring systems. Prof. McLaren holds a Ph.D. and M.S. in Intelligent Systems from the University of Pittsburgh.

Gloria J. Miller has a doctorate, master's and a bachelor degree and has more than 20 years of project leadership experience. She has authored methodologies and books to implement software engagements and modernize organizations. Gloria is founder of the IT and management consultancy company maxmetrics.

Christiane Molina is a professor and researcher of the Strategy and Leadership Department at EGADE Business School, Tecnologico de Monterrey and she is Academic and Research Director of the Conscious Enterprise Center. She specializes in strategy and sustainability and holds a Ph.D. degree in Management and an MBA from EGADE.

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Luca Morini is Assistant Professor at the Centre for Global Learning (GLEA) of Coventry University. Luca's main areas of interest are critical pedagogy, systems thinking and co-creative research methodologies. Luca publishes widely on the diverse themes of digital and critical pedagogy, game design and learning, ecology of education, decolonisation and research methodology.

Peter Mozelius is a senior lecturer and researcher, working at the Department of Computer and Systems Science at the Mid Sweden University in Östersund, Sweden. Research interests are in the areas of Information systems, Technology enhanced learning, Game-based learning, and Programming education.

Sandra Mühlböck: Professor of Industrial Management and Product Development (University of Applied Sciences Upper Austria) and has several years of practical experience in the field of R&D management accounting. Research areas are management and project accounting and business model development. Since 2018, she has been increasingly involved in the topic of gamification and edutainment.

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).

Mathieu Muratet is assistant professor in computer science at INS HEA and member of the MOCAH team at LIP6 laboratory (Sorbonne University). His research topics focus on Serious Games used for learning purposes. He is interested in Serious Games to study their design and to analyse learner's traces.

Ekaterina Muravevskaia is a researcher in Human-Centered Computing field. She also worked in the IT Industry for five years. She received her PhD in computer science from University of Florida in 2021. Ekaterina's research is about using virtual reality technologies for developing empathy in young children.

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John Nietfeld: The author team includes scholars and graduate students from North Carolina State University and The Pennsylvania State University who study metacognition, self-regulated learning, and learning from expository text. In their work they employ emerging technologies and game-based learning to implement interventions that support student interest, engagement, and academic achievement outcomes.

Jorge Oceja is a teacher, ed. Psychologist, M.A in instructional design and Ph.D. in Game Studies. He has been the director of the Fundación Botín educational program and he has worked extensively in the public and private sector. He has taught in in Spain, UK, and USA. He works at the University of Cantabria.

Kristine Øygardslia is an associate professor at Nord University (previously a postdoctoral researcher at the Norwegian University of Science and Technology). She has a background in computer games for

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Provocative Games to Encourage Critical Reflection

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Abstract: The SECRIOUS project takes a game-based approach to improving knowledge and attitudes in cybersecurity practices. Our methodology includes interdisciplinary Serious Game co-design with coders and aims to produce critical reflection on participants' own coding practice. To encourage this we created a series of Small Provoking Games (SPGs) about the project's three overarching topics (Code Security; API Security; Security Lifecycle) and five co-produced themes (Coder Practices; Code Motivation; Morality; Resources; Communication). Games and play are well-suited for creating both reflection-in-action and reflection-on-action. Provoking a lasting change in attitudes towards secure coding practice requires dialogic or inquiry-based reflection leading to transformative reflection We define a 'provoking game' as one that uses the techniques of reflective game design to produce cognitive and affective challenge – a eudaimonic appreciation of the player experience. This emphasises a player's sense of purpose and aims to create exo-transformation (change in attitudes and/or practice outside the game.) SPG design foregrounded Khaled's principles of reflective game design and was led by serious game experts, a cybersecurity expert, and a playwright, and included input from the entire SECRIOUS team to define each game's specific focus. Two SPGs were produced: Protection (which challenges the assumption of 'absolute' cybersecurity protection) and Collaboration (which highlights communication in cybersecurity developer teams.) A third game is in development. SPGs feature highly exploratory gameplay, expected failure, and focus on metaphor (of both game objects and player actions) to create doubt, contradicting existing mental models and encouraging the players to question the game rules and underlying concepts. The games were used within game-jams to provoke critical discussion, a creative mindset, and group reflection. This paper analyses the design process of these two SPGs and reflects on our contribution to reflective game design.

Keywords: Serious Games, reflective game design, critical thinking, cybersecurity, reflection

1. Introduction

The overall goal of the SECRIOUS project is to engage coders in cybersecurity issues as both players and designers of serious games. The main problem was defined not as a lack of knowledge resources but as a need to shift attitudes towards attaining and effectively using knowledge about cybersecurity. To achieve this, our methods needed to 1) encourage critical reflection leading to attitudinal and behavioural change and 2) elicit the nature of cybersecurity practice. Provoking a lasting change in attitudes towards secure coding practice requires dialogic or inquiry-based reflection leading to transformative reflection (Baumer, 2015; Mekler, Iacovides and Bopp, 2018). Small, provoking games (SPGs) are proposed as an effective method for interventions that aim to challenge learners' (false) preconceptions and create revised understandings. We define a 'provoking game' as one that uses the techniques of reflective game design to produce cognitive and affective challenge and aims to create exo-transformation (change in attitudes and/or practice outside the game) (Mekler, Iacovides and Bopp, 2018). In this sense, SPGs are about players' self-awareness and attitude shift with regards to their subject matter.

As well as functioning as standalone games, our SPGs were specifically designed to enmesh with our cybersecurity game jams to provoke reflection and contribute to the co-design process of new serious games arising out of the game jam. As such, the SPGs play a part in wider methodological development for the co-design of serious games. This paper covers the context of using serious games to provoke critical reflection, our methodology and methods, an analysis of the games themselves (both available at SECRIOUS, 2022), and our reflections on this process.

2. Research background

The concept of 'reflection' has been defined in numerous ways and there is no single, widely-accepted definition. However, literature reviews (Atkins and Murphy, 2018; Reflection Toolkit, 2020) note that despite the range, complexity, and abstraction of scholarly writing on reflection, differences are typically around terminology and the structure of the metacognitive process. Definitions tend to share three main elements which can be summarised simply as: reflection is a *conscious exploration* of the *self* to *construct new insights*. Furthermore, the literature tends to agree on three key stages of reflection: Breakdown (also called discomfort, surprise,

conflict, or dissonance); followed by Inquiry (analysis); which may lead to Transformation (new perspective, affective and/or cognitive change) (Schön, 1992; Baumer, 2015; Atkins and Murphy, 2018).

The depth of reflection is defined in different ways and using different terminology. Depth is typically structured as a hierarchy from superficial observations, through intentional inquiry and/or dialogic reflection which constructs links to one's own experiences and/or wider social and ethical constructs, to truly transformative and/or critical reflection that results in a meaningful shift in beliefs, approach, or behaviour and that extends into the future. Critical reflection specifically includes "bringing unconscious aspects of experience to conscious awareness" (Sengers *et al.*, 2005, p. 50).

Existing literature on reflection within serious games notes that many games' purposes go beyond knowledge acquisition and aim for attitudinal or behavioural change, for which reflection at least at the level of constructing relationships between a game and real life is required (Khaled, 2018; Mekler, Iacovides and Bopp, 2018; Whitby, Deterding and Iacovides, 2019). Khaled notes that simulations of real life processes afford reflection as they "explicitly represent systems of beliefs, propositions and processes [...] enabling interrogations of validity" (2018, p. 5), a characteristic shared by games. However, "Unlike simulations, games are inextricably linked with the notion of designed challenge and often also with difficulty. [...] Non-trivial challenge, analysis and problem solving, key parts of the reflective process, are already present in how we generally understand games." (pp.5-6). Mekler, Iacovides and Bopp also state that games are particularly suitable for supporting reflection as they "confront players with puzzling or surprising situations, which invite them to plan, experiment and look for new solutions" (2018, p. 315) , matching the three key stages of reflection. Schön (1992) distinguishes reflection-in-action as synchronous with practice and reflection-on-action, which occurs after the activity has taken place. Reflection-on-action can (but does not necessarily) result in behavioural/attitudinal change and can also feed back into reflection-in-action. In the context of serious games, a combination of both types of reflection can result in-game reflective processes (e.g. developing your conceptualisation of the game or altering your play style) and out-of-game changes in, for example, self-image or behaviours (Whitby, Deterding and Iacovides, 2019). Games' potential clearly reaches beyond reflection-in-game as the fictionalised challenges both provoke curiosity and grant agency, which supports reflection in out-of-game contexts (cf. Khaled, 2018, p. 22), demonstrating again the real potential for games as a medium to support transformative reflection.

Various principles for reflective game design have been proposed, although there is no unified approach (Kitson *et al.*, 2019). It is important to begin by challenging the assumption of 'fun' that is still common in research on serious games. Serious games can, of course, be fun however, a more important concept is that of the 'serious experience' (Mekler, Iacovides and Bopp, 2018), where negative emotions can lead to positive experiences, producing eudamonic appreciation (i.e. contentment from having purpose in life). In other words, games can be *rewarding*, whether or not they are also *enjoyable*. This concept is particularly important when considering reflective game design and it is noted that greater cognitive and affective challenge tend to lead to greater appreciation (Whitby, Deterding and Iacovides, 2019 p.340). Kitson *et al.* note that "although we can use technology to design for transformative experiences, we do not design the experiences themselves but rather create the conditions to invite them" (2019, p. 2). Useful analyses of design qualities that inhibit or encourage reflection in game design (Sengers *et al.*, 2005; Khaled, 2018; Mekler, Iacovides and Bopp, 2018; Whitby, Deterding and Iacovides, 2019) have been synthesised into our recommendations for reflective game design:

- Provide for interpretive flexibility (Sengers *et al.*, 2005) to encourage the active construction of meaning crucial for reflection and meaningful 'questions over answers' (Khaled, 2018, p. 23).
- Expose unconscious aspects through challenging player expectations (of game systems, narrative, content, and external assumptions) (Sengers *et al.*, 2005; Khaled, 2018; Mekler, Iacovides and Bopp, 2018); explicitly designing to "engage, problematise, and potentially conflict with cultural and social norms" (Whitby, Deterding and Iacovides, 2019, p. 339); and making learning clear and conscious (Khaled, 2018, p. 23).
- Create player actions/decisions that are emotionally or cognitively meaningful to increase eudaimonia and extended reflection (Whitby, Deterding and Iacovides, 2019, p. 345).
- Provoke the player. Khaled calls this "Disruption over comfort" and notes that "Games that are designed to disrupt can create opportunities for players to be thoughtful, creative and innovative"(2018, p. 23). It includes techniques of distancing, surprise, and failure to help trigger the critical analysis necessary to contradict an existing mental model. However, it is also crucial that provocation needs to be well-balanced for player engagement.

3. Provoking game design

Drawing on the recommendations for reflective game design above, our main emphasis (in both design process and SPG product) was on: *interpretive flexibility*; *disruption of/subverting* expectations; *expected failure/frustration* during construction of meaning; explicit *out-of-game reflection*; and *rigour*. Our aim was to focus players' attention on critically examining the game object's behaviours and the rules governing their interactions. Therefore, the majority of player responses should take place at the meta level - outside of the game. To maximise critical reflection, we defined overall principles for designing the SPGs.

1. Abstraction of the content entities to their essential properties and methods, and re-rendition in a fictional, unconventional metaphor.
2. Integration with out-of-game activity to re-contextualise game content and experience within the domain of cybersecurity.
3. Use of metaphor to "mask" familiar content and create the distance conducive to critical reflection.

3.1 Interdisciplinary co-design

SPG design was in the context of a highly interdisciplinary research project and it was crucial to maximise the different types of expertise within this team. This paper's authors (all serious game specialists) worked closely with a cybersecurity expert and a playwright. This collaboration was particularly fruitful as it allowed thorough and nuanced investigations of the problem area, focussing on the most important intended outcomes. This laid rigorous groundwork for a well-scoped serious game intervention. The cybersecurity expert ensured the validity of the content and its modelling, whilst the playwright was crucial in producing a creative, unconventional metaphor, as well as designing an engaging overall narrative and story beats for the games. Furthermore, the entire SECRIOUS research team was involved in ideation for each game's subject, and contributed feedback, validation, and oversight throughout the design and development process. We consider this interdisciplinary approach to have been absolutely crucial for rigour.

3.2 Design and implementation of two provoking games for cybersecurity

3.2.1 Triadic Game Design

Triadic Game Design (TGD) is well-established as a rigorous serious game design method and can also be used for documentation and evaluation (Harteveld, 2011). TGD breaks serious game design into three aspects: Reality (where the investigation of the problem area and the associated subject matter takes place); Meaning (where the intervention strategy to generate change is designed) and Play (where the gameplay to best achieve this change is designed.)

The Reality aspect was analysed in interdisciplinary meetings with the support of data gathered in user-centred workshops that SECRIOUS held for this purpose, cross-referenced with related literature to clearly define each problem area and establish priorities. An ideation phase focussed on creating questions inspired by the project's three overarching topics (Code Security; API Security; Security Lifecycle) and five co-produced themes (Coder Practices; Code Motivation; Morality; Resources; Communication). These questions were used to identify an overall concept for three SPGs which together cover these topics and themes. (This paper considers the first two games; the third is currently in development.) Each SPG design process started with the preconceptions that we aimed to target in each game's audience. Led by cybersecurity experts, we composed a set of entities/concepts essential to the specific subject in question and defined key messages that the game should convey.

For the Meaning phase, we drew explicitly on the principles of design-for-reflection to produce an intervention strategy with a list of associated learning mechanics. Using guidance for serious game workflows (Abbott, 2020) we defined: 1) intended outcomes; 2) learning context; 3) learning behaviours (using Bloom's Taxonomy (Anderson and Krathwohl, 2001)); and 4) emotional design. We then used this information to select appropriate Learning Mechanics (LMs) from the Learning Mechanic Game Mechanic (LM-GM) Framework (Lim *et al.*, 2013). We also considered the LMs for the post-play activity as these 'out of game' reflections were core to our strategy.

For the Play phase, we worked with the playwright to devise a premise for a comprehensive metaphor and a loose narrative plot to cover the intended outcomes arising from the Reality and Meaning phases. Working with the cybersecurity expert, we translated subject matter entities into in-game objects and the subject matter principles into game rules. LMs were mapped directly to appropriate Game Mechanics (GMs). We shortlisted a set of genres and play-styles appropriate to the LM-GM mappings and content, formulated player actions, and

designed the serious gameplay loops. We also specified in-game performance assessments, win/lose conditions and concluded with level design, which was directed to stage in-game events inspired by real-life conditions. These activities all drew directly from the LM-GM mapping that arose from the TGD process. It is important to note that this is not a fully linear process and iterative design cycles clarified and reinforced elements in all three phases. Lastly, game designers specified the content for the post-play activity. The specific design of each SPG is summarised below.

3.2.2 SPG#1: Protection

The first SPG, named Protection, was designed to address the following preconceptions:

- Coders think cybersecurity is an optional and obscure feature that is the domain of dedicated experts, rather than an essential aspect of any application.
- Coders think that cybersecurity is binary, instead of thinking in terms of a fluid and changing landscape of risk that is in constant need of re-assessment.
- Coders not appreciating the diverse range of mitigation strategies and their suitability towards certain threats, or compatibility to each other.
- Coders thinking of cybersecurity as an independent layer with a view of "the more the better", whereas it is an integral part that should be balanced with functionality.

This led to the definition of the following learning outcomes. After playing players should:

- Perceive cybersecurity as a crucial component of any system
- Reflect on their own coding practice.
- Understand that absolute security is not possible.
- Understand that risk assessment is contextual and can fluctuate over time.
- Grasp the concepts of risk, threat and countermeasures and figure out that threats and defences have multiple (1-many) relationships.
- Acknowledge that security features may have functionality trade-offs.

The most relevant Learning Mechanics were the *Simulation* of a fictional yet recognisable situation which allows players to *Explore* and use *Experimentation* with *Feedback* to reverse-engineer the rules of the game which in turn allows them to *Analyse* and *Plan* how to succeed. We explicitly excluded *Instruction* and *Guidance*, however, implicitly in the meta-game and explicitly in the post-play activity, the player is prompted to compare how these rules reflect or contradict their own mental model of their cybersecurity practices. To serve these LMs, we selected the core Game Mechanics of *Movement* (to explore and avoid threats), *Collection* (of defences/mitigations), *Design/Editing* (of a defence strategy), and *Strategy/Planning* (to adapt to changing contexts). Figure 1 shows the gameplay loop with associated Learning and Game Mechanics.

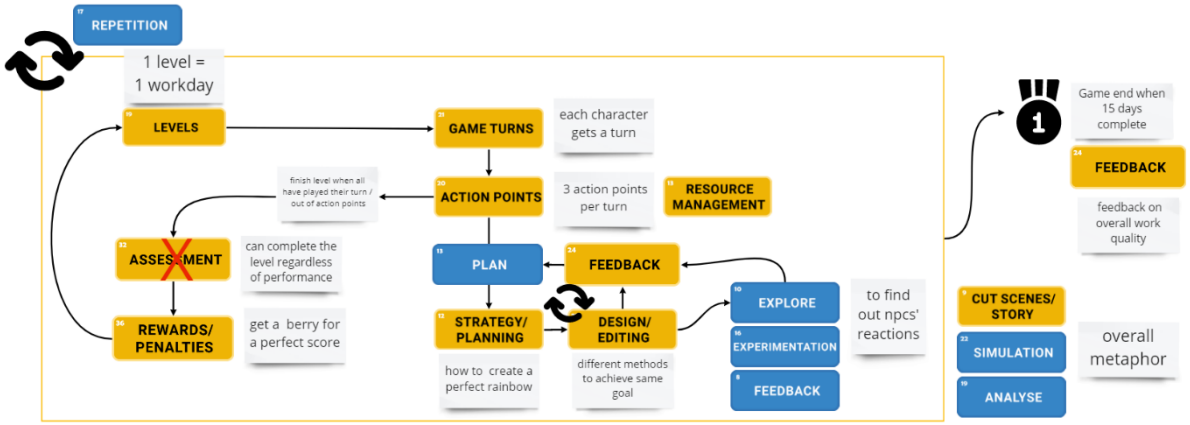


Figure 1: gameplay loop showing mapping of Learning and Game Mechanics for Protection

We then designed the core metaphors for game objects and game rules. These are summarised in Table 1, Figure 2, and Figure 3.

Table 1: each game object with its justification for Protection

Game object	Justification
Main character	A hybrid biological/electronic entity to convey the universality of the concept of security.
Digital rainforest	An ecosystem of software applications with a changing context (day-night cycle represents abundance vs scarcity).
Plants	Data suppliers.
Berries	Data that the character can process: beneficial orange berries give power (juice) to the main character; harmful purple berries (poison) have a delayed corruption effect (as from malware) and blue berries stick the main character's mouth shut, mimicking a distributed denial of service attack.
Malicious agents	Hackers. Each predator has a different movement pattern (patrol, hunt, spring-trap) and damage effects representing common attack methods, such as control hijacking, process shut down, asset theft, etc.
System parts	Cybersecurity defence strategies that negate or mitigate negative effects and increase main character's functionality and ability to avoid threats.



Figure 2: Protection game objects

Game rules, reflecting the principles laid down during the Reality phase, are:

- A character starts unable to defend themselves and needs to collect and install system parts for defence. Installing defence modules takes time and resources.
- Some threats can be rendered obsolete by installing the proper defence modules, some can only be mitigated, while for others there are no defences and the player needs to avoid those threats.
- Some threats can become more or less dangerous based on other conditions. For example, blood sucking mosquitos become more dangerous if the player is paralyzed by a spider and cannot escape.
- Some defence modules render others useless, while some defence modules complement each other. E.g. a filter module at the I/O port (prevention mechanic) makes the database compartmentalization module (contingency mechanic) redundant.
- Installing the most impervious defence module significantly increases resource consumption and limits functionality.
- Installing too many defence modules causes system overload and triggers a non-responsive state until upgrades are uninstalled.

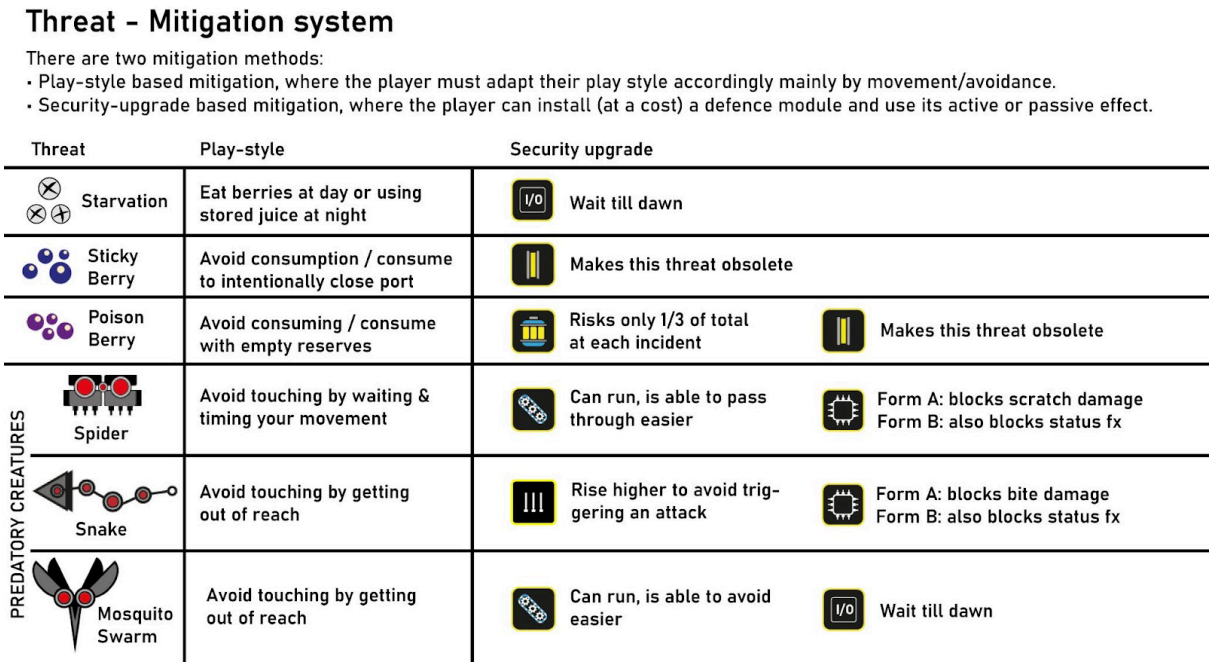


Figure 3 – Summary of Threat-Mitigation interactions in Protection

In terms of gameplay, Protection is a short, 2D, side-scrolling, real-time, single-player game with genre elements from action (move/avoid/collect), strategy (manage resources/select) and puzzle (choose/combine). The player must navigate a risky landscape, trying to survive against various threats using diverse defence systems. Our design avoided common tropes associated with these genres (e.g. score, time pressure, lifecount), allowing instead the exploratory approach conducive to critical thinking. Productive failure is a core concept and the player is expected to 'die' at least once as they gather information. The player must analyse feedback loops to discern the game's rules and create defence responses. Feedback is frequently counterintuitive or surprising, subverting players' expectations. The three main in-game actions are moving, collecting, and installing/uninstalling defence systems (the main educational player action, mirroring the process of risk assessment and defensive planning). This requires the player to first find the respective module (which represents gaining and updating knowledge in real life.) Protection is single-player to serve our goal of inquiry-based reflection on an individual's own practice.

The story takes the protagonist on a journey of natural evolution and intentional change, starting with the protagonist becoming aware of their own existence and expanding into developing movement and a metabolic cycle (input/output). Intentional change is ensuring survival by installing combinations of defence systems. The character has no explicit purpose other than surviving in its harsh, native environment. The story concludes with the protagonist symbolically mastering these conditions and flying away. In the post-play activity, players were asked to interpret in cybersecurity terms what they thought the entities represented and what they deduced from the story.

3.2.3 SPG#2: Collaboration

The second SPG, Collaboration, was designed to address these problem areas:

- Developers (or teams) working on different parts of the code tend to operate in an isolated way and cybersecurity issues can creep in due to a lack of overview and/or communication.
- Developers may not treat communication as an important part of their job and consequently may not be willing to devote time and energy to it.
- Human/"soft" skills are an undervalued and frequently untrained skill set in highly technical work environments but are crucial for successful project delivery and good work conditions.

This led to the following core learning outcomes. After playing players should:

- Understand that the security of the product is only as good as the security of the weakest link.
- Understand that the quality of communication across teams can affect the quality of the end-product.

- Appreciate that the human side of communication is as important, energy consuming and skilled as the technical content.
- Grasp that security needs to be implemented in multiple aspects and stages, therefore overview and communication throughout the development pipeline is necessary.
- Reflect on their own communication skills and cybersecurity contexts.

Learning Mechanics were identical to Protection, however, this time they were mapped to *Levels* and *Game Turns* (representing time in the Security Lifecycle), *Action Points* (representing worker time/resources), and the same *Planning*, *Design*, *Resource Management*, *Feedback* cycle as in Protection. See Figure 4.

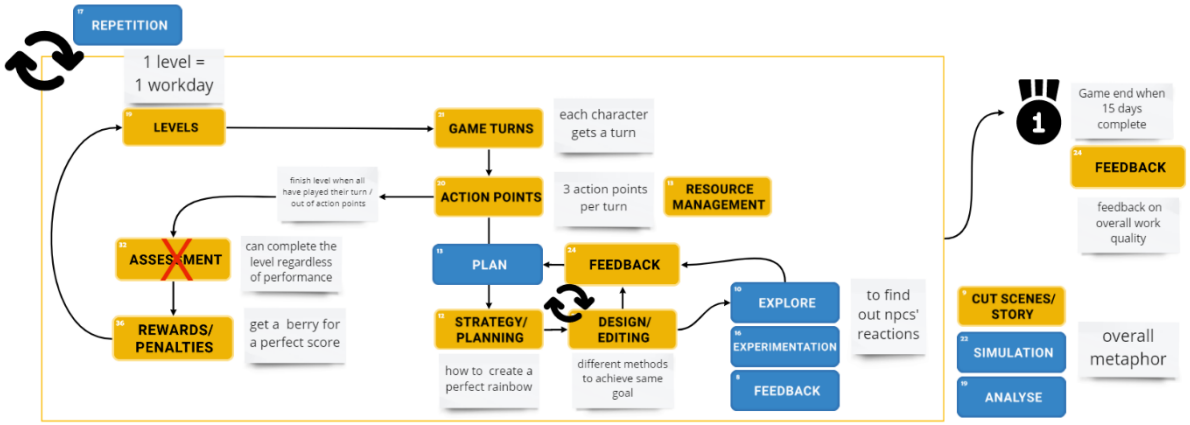


Figure 4: gameplay loop showing mapping of Learning and Game Mechanics for Collaboration

We then designed the core metaphors for game objects and game rules. Collaboration adopts the same fictional universe with its light-hearted tone and colourful iconography as Protection, but expands the list of in-game entities, summarised in Table 2 and Figure 5.

Table 2: each game object with its justification for Collaboration

Game object	Justification
The Rainbow	An infrastructure that outputs 'rain' into the digital rainforest, representing a publicly-used software application with its seven coloured lanes representing the dimensions of the cybersecurity requirements.
Rain	Data flow that can become corrupted without secure infrastructure.
Trees	The user community that relies on the infrastructure to serve a vital need, and the variable health of the ecosystem.
Monsoon season	Represents the duration of the team project: 15 days (15 game levels.)
Main character	The same main character as Protection.
Other characters	Various colleagues, similar but distinct creatures with their own personalities (expressed by face) and expertises (expressed by colour).

Collaboration game rules are:

- Each co-worker can construct lanes in their own colour/expertise. Some roles can combine their efforts to construct lanes in a composite colour. Some roles are unique and impossible to substitute.
- Each co-worker has their own personality and default mood/behaviour ranging from highly motivated through indifferent to opposed to the project's goal.
- Talking to NPC co-workers influences their mood and behaviour. Each personality responds differently to various communication styles.
- At the end of a work day, the Rainbow should have all 7 coloured lanes. Each missing or incorrect lane reduces the cybersecurity quality of the Rainbow and contributes to Rain acidification.
- Acid rain impacts the health of the ecosystem. Damage accumulates over the duration of the monsoon season.
- There is no personal reward or penalty for the team members for the quality of their work. The only feedback that exists is the observed health of the ecosystem.

- There is no fail threshold for each level, or for the game overall. A player is allowed to complete a level (commit code) no matter what cybersecurity quality the Rainbow has
- Damage done to the ecosystem can be ameliorated to a small degree using berries, which are generated if a level is completed with a perfect score.

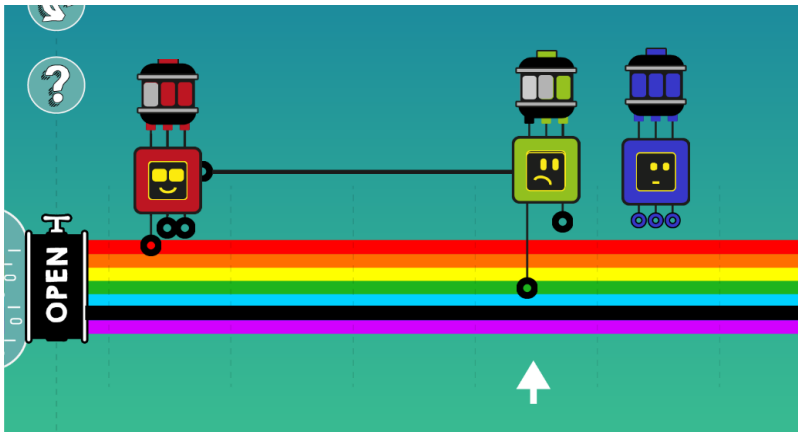


Figure 5: cropped screenshot from Collaboration showing communication and different moods

Collaboration is a turn-based, puzzle game, with each level representing a work day and a whole game run representing a software project. Collaboration is single-player with AI agents to model specific behaviours. The puzzle for each level is to find the appropriate actions to take in order to make the safest Rainbow possible. This requires players to learn/recall the order of colours in the Rainbow (an abstraction of technical skills), and also observe and understand their colleagues' personalities (the human aspect). The challenges are designed to be not always feasible or perfectible. Furthermore, the challenges frequently have more than one solution representing different approaches to problem-solving. In Collaboration, time was quantified in work shifts and had a sense of chronological order which led us to adopt the turn-based approach. Space was irrelevant as a concept which led to a single, static level design where all actions took place. Main variables for each level were the team composition and the Rainbow puzzle, allowing for levels to be procedurally generated. Action points were an essential mechanic to signify units of energy/time during a work shift. The player can choose to spend their action points constructing a rainbow lane (writing code) or communicating with their co-workers. This is a direct translation of the key message that communicating is as essential and time consuming as coding, but also equally an integral part of development work.

As in Protection, players were asked to undertake a post-game activity and describe in cybersecurity terms what (they thought) the entities reflected, but this time players were also asked to directly reflect on how they manage their real-life work relationships and compare that to in-game events.

4. Discussion

These two SPGs appear, on some level, to be quite different. In Collaboration, players have a clear premise, identity, and objective and the game rules are highly scaffolded with a tutorial and reference manual. On the contrary, in Protection, players have ambiguity and freedom with instructions limited to the game controls and absolutely everything else open to interpretation. However, both games were designed with the fundamental concept of provocation through both the subverting of player expectations and of withholding information about the game rules which forces players to experiment, explore, and actively construct their own meanings and mental models. Game differences are to focus the player's attention to best achieve each game's intended outcomes. An evaluation of the SPGs in terms of their effectiveness in achieving reflection is outside the scope of this paper (detailed evaluation is forthcoming). However, we can comment on preliminary results from using Protection and Collaboration within Serious Game Jams on the SECRIOUS project.

Firstly, the abstraction of technical detail and focus on visualising concepts and processes through a friendly metaphor made our SPGs an ideal medium for introducing cybersecurity to a novice audience. Cybersecurity is not often depicted in such a playful manner and this could help to promote engagement. Player feedback on the graphical style was very positive, whilst noting that the game setting was "difficult to interpret". The adoption of metaphor makes the post-play activity essential to a complete SPG experience as, whilst the games in isolation could create critical reflection, our overall purpose was reflection as part of co-design activities. Post-play

reflection is an established technique in simulation-based training where an 'after-action review' helps players to receive extrinsic feedback, gain an overview, and analyse their performance (Meliza, Goldberg and Lampton, 2007). Our goal was rather to create dialogue as players compared and contrasted different interpretations of the metaphor and, by doing so, deepen their understanding of and relationship to cybersecurity concepts. Recontextualization during the post-play activity actively prompted players to compare their in-game experience with their real-life practices and note any new observations arising and their potential implications in real world terms. Post-play reflections demonstrated a variety of interpretations of character identity and which threat-defence combination was the most useful, implying different critical judgements (or at least different play styles). Furthermore, players effectively analysed and re-mapped the in-game content to SECRIOUS Cybersecurity Concept Cards (a forthcoming SECRIOUS output), with some very insightful responses. Therefore, we consider the ambiguity in asset design and gameplay to be successful.

Our SPGs excluded mechanics that promote 'gamified' engagement, such as competition and rewards. Protection also eschewed any instructions to orient the player. Furthermore, the games had a hybrid genre style, for example, Protection looked and felt like a platformer but control mastery was not the way to win, it was instead strategic thinking. It could be argued that this unfamiliar gameplay encourages reflection, however they may also have decreased engagement. In Protection players were initially confused (one asked "Are were supposed to know how to do this?"), however, continued experimentation allowed players to construct meaningful connections between game events and cybersecurity concepts. Players did express surprise (and sometimes frustration) during gameplay, especially at points that had been designed to challenge expectations or provoke 'out of the box' thinking, for example, the realisation in Collaboration that it was not possible to always get a perfect score, or the narrative twist in Protection that too many upgrades causes an overload.

Finally, it is important to note that our SPGs were designed as a single (or limited) user experience. Replayability was not a design goal and the focus was firmly on their place within a wider educational and creative methodology. This implies that SPGs for similar purposes could be made even shorter to improve completion whilst still providing the basis for critical reflection.

5. Conclusion

We have presented the rigorous design process of two Small Provoking Games which feature highly exploratory gameplay, expected failure, and focus on metaphor. We integrated gameplay experience with a range of post-game activities designed to create doubt, contradict existing mental models, and encourage players to reflect on underlying concepts and make links with real-world practice. Whilst evaluation is still in progress, it can be seen that these provoking games have been successful in creating ambiguity, meaningful connections, and an accessible introduction to cybersecurity concepts. A formal evaluation will follow to analyse if these characteristics have been successful in our core goals of 1) creating inquiry-based reflection, and 2) supporting players in the move from consumers of cybersecurity-themed games to co-designers.

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Game Designers' Perspectives: Interception between Games and Educational Games Design

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Abstract: Games and Educational Games(EGs)! To what extent do they diverge? How do game designers approach such apposition? The extensive need for games in and outside classrooms demands clarity between games and EGs through game designers' perspectives. In the Australian context, game designers have witnessed technological advancement, the user-expectation, and the use of games within various contexts, including the classroom. The transformation in technology and the need to adapt and design games corresponds to the needs and requirements of its end-users. Admittedly, it has been overlooked in gaming studies if the designing processes and their perception differs between games and EGs. Respecting that aspect and the knowledge adapted by game designers to achieve players' experience successfully, we first need to comprehend how game designers position games and EGs within their context, their experience constructed over time, and their beliefs. Therefore, this paper interprets seventeen game designers' perspectives through semi-structured interviews in Australia. The data is thematically categorized, coded, and analyzed using NVivo. The results are presented through the interpretivism paradigm, which is grounded in the theoretical implications based on Dewey's theory of experience and concepts to gather the 'essence' of game designers' experience. Furthermore, a conceptual basis is established for game designers and learning designers to consider while designing games and EGs.

Keywords: Game designers, balance, fun, active experience, educational games, experiential learning, game design

1. Introduction

Games include 'all games' where learners improve their in-game skills, whereas EGs transfer the knowledge developed during game playing (Rick & Weber, 2010). The literature argues that existing beliefs that promote understanding real-world concepts through realistic scenarios allow learners to achieve learning outcomes of a particular subject (Beavis, Dezuanni, & O'Mara, 2017; Stieler-Hunt & Jones, 2015). However, evidence is absent on whether game designers' beliefs complement the models proposed for games or educational games (EGs). Although the history of Australian videogame making has been researched by prominent academics (Apperley, 2008; Banks & Cunningham, 2016; Swalwell, 2012), it is crucial to understand how the video game industry and the game designers are positioned in the emergence of the industry.

The essence of a "game" is problem-solving, with which competence is developed through trial-and-error and exploration of learning practices (Koster, 2013; Schell, 2008). The transition between games as entertainment and for educational purposes is designed somewhat similarly. However, the process of designing an EG equipped with fun and educators' perspectives has had its own challenges. EGs are remarkable motivational power tools including challenges that excite players, teach and master achievements: "It is the act of solving puzzles that makes games fun… with games, learning is the drug" (Koster, 2013). A cross-disciplinary integrative approach to enhance learning is proposed (De Freitas, 2018); however, balancing game playability, fun, and the learning outcome remains challenging. In response, a recent study advocated the need to empirically and theoretically gather individual experiences of "video game makers" more vividly to obtain a broader range of perspectives across video game production (Keogh, 2021). This indicates a lack of evidence on game deisgners' experiences and perspectives and how their decision-making processes are undertaken in their daily activities (Keogh, 2019, 2021; Sotamaa & Svelch, 2021), and perhaps, the need to explore whether their experiences influence their future game and EGs projects.

Understanding game design is tricky: "Design is a process by which a designer creates a context to be encountered by a participant, and from which meaning emerges" (Salen & Zimmerman, 2004). Notedly, meaning emerges through 'play,' a voluntary 'nature of act' where the 'desire' of participating in a game increases motivation and gives purpose (De Castell & Jenson, 2007). I argue that the learning experience is highly crucial and predominantly rooted in Dewey's theory of experience (Dewey, 1938) and Kolb's experiential learning (Kolb, 1984, 2014). Most research focuses on the players' experiences during gameplay; however, game designers' and teachers' learning experiences are still under-researched despite their vital position in designing EGs. EG design has been perceived and examined differently across disciplines for specific purposes, including creating research-based games for educational impact (Gaydos, 2015). Some of the characteristics emerging in recent

years include learning outcomes, usability, user's experience, motivation, engagement, game design, user satisfaction, usefulness, understandability, performance, playability, pedagogical aspects, efficacy, social impact, cognitive behavior, enjoyment, acceptance, and user interface (de Aguiar, Winn, Cezarotto, Battaiola, & Gomes, 2018; Shi & Shih, 2015; Wouters & van Oostendorp, 2017).

Despite the existence of many successful EGs, there have been many unsuccessful cases as well. Game designers do not create replicas of well-recognized games, or perhaps, we are unaware of what game designers perceive. This paper reports game designers' perspectives, including actively experiencing designing games and EGs, integrating game elements and core concepts to maximize the games' effectiveness and increase the possibilities of achieving learning outcomes and levels of engagement and motivation (Kalmpourtzis, 2018; Schell, 2008). Furthermore, the study provides answers to how game designers balance features between games and EGs, how they adapt such orientation., and whether they consider any formally published definitions of games or EGs in their practice.

2. Related Literature

Defining games is versatile as it adapts differently to the genre/concept required. A review of 60 definitions sheds light on different game design requirements and complexities desired within an end product (Stenros, 2017). Nevertheless, it is yet to empirically build upon an ontological foundation to avoid building limitations around the field of inquiry as the designing processes of games have become adaptable in nature (Gaydos, 2015). Games have been identified as highly motivating and engaging tools for 21st-century skills and the tech-savvy generation. Mastering new challenges using trial-and-error approaches and repetition of a task to understand better the concepts demonstrate positive learning through playing games (Barab, Pettyjohn, Gresalfi, Volk, & Solomou, 2012; Young et al., 2012). However, binding game design elements into educational learning outcomes has factually generated positive and negative results (De Castell & Jenson, 2007; Young et al., 2012). As defined, a game is *"a system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome"* (Salen & Zimmerman, 2004). "Meaningful Play" combines actions (descriptive) and outcomes (evaluative) within a magic circle to add the emotional experience of playing games through a game system. Players use a free activity to consciously experience impressiveness through play, and games provide an opportunity for play, resulting in flow experiences (Gaver, 2002).

For decades, games have been valuable in different contexts (in a classroom or outside). It has been argued that games are not entirely extraordinary (Kultima, Lassheikki, Park, & Kauppinen, 2020) and that the argument where what is valuable in games or what is good game design needs explicit clarifications. It is difficult to identify whether players 'feel' through play and whether it relates to the game's design that is neither fun nor educational. Such pitfalls are not surprising because designing EGs that fulfill the seemingly contradictory functions of fun and seriousness is challenging (Flanagan, 2009). It has been established that games with seamless integration, also called an *endogenous* design (Athavale & Dalvi, 2019), are effective as they harness the intrinsic motivation of games for delivering learning (Gaydos, 2015). The current era is challenging and competitive when games are positioned in various contexts, and their use heavily depends on how it is utilized (Stenros, 2017). Undoubtedly, games have become a normalized 'activity' across many educational and entertainment industries where communication, expressing versatility in ideas, and creating memorable experiences are concerned. As highlighted, *"Game designers need as well consider the specific needs of teachers, parents, instructors or non-formal educational institutions who are responsible for the implementation of serious games into their educational praxis or curricula."*(Slussareff, Braad, Wilkinson, & Strååt, 2016).

3. Theoretical and Conceptual Relevance of Data Analysis and Interpretation

The conceptual and theoretical framework adopted in this paper relates to Dewey's theory of experience (1938) concepts such as the *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 construct new knowledge that welcomes the subjectivity of individual experiences (Dewey, 1938). The *growth* of experience represents how individuals grow in their careers, experience 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 involves "the foresight of the consequences that may result from acting upon that impulse" (1938, p.67). Game designers create meaning and constantly reflect through their actions as the games are play-tested, designed, prototyped, iterated, or conceptualized. Hence, deriving an enriched experience shows an individualized aspect of comprehending how game designers differentiate games and EGs and how they distinguish between those above and their dilemmas in the decision-making process that requires their attention. The principle of *continuity* is where each experience taken from the past affects the future experience of the individual.

In contrast, *interaction* is referred to the situational and game designers' influence on players' or students' experiences. Dewey believes that the elements of *interaction* and the *situation* occur concurrently. Some challenges may be encountered despite the importance of experience, such as "that all experiences are genuinely or equally educative" (1938, p.13). Hence, the game designers 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. Therefore, it is directly relevant to how game designers evaluate players' experience while playing the game. In this context, it does not matter whether the player is a gamer or a learner. This is related to how game designers design the interaction for every individual's needs, support their cultural and social differences, and allow them to learn/play equally and freely. Experience, 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.

The theory of experience has been discussed and applied in many fields. The prominent Kolb's cyclic model (1984) of experiential theory was built on the works of Dewey and has provided its means in the field of education and EGs. As described above, experiential learning is simply defined from the perspective of how learners experience a phenomenon and use that to facilitate learning. It has become a mutual ground for both teachers and game designers attempting to integrate game-based learning with education (Appelman, 2005; Kolb, 1984; Salen & Zimmerman, 2004):

- Learning involves participation in the real-world
- There are intimate relations between experience and education
- Understandings are derived from and modified through experience
- Meaningful learning consists of action and reflection. Experiential learning is also based on the belief that people learn best by doing.

3.1 Participant Recruitment, Data Collection, and Data Analysis

Initially, the location was set in Victoria, Australia; however, due to the pandemic, location expansion was obligatory. With criterion and snowballing recruitment procedures, semi-structured qualitative interviews with 17 game designers in Australia were completed (January 2020-October 2020). The criteria set for the recruitment process are shown in Table 1. Each interview session was approximately 2 hrs and 30 minutes (Zoom, Discord, MS Teams). The current paper interprets one central theme (six themes) emerging through the coding analysis. Consequently, the phenomenological approach was adopted to allow the researcher to uncover the essence of lived experiences described, as the qualitative researcher pursued to identify the phenomenon of human experience and then derive a description representing the experience's very nature (Kafle, 2011). The essence should not be viewed as a vague idea but rather the ability to identify the meaning embodied in the lived experience (Merleau-Ponty & Smith, 1962).

Table 1: Participant recruitment criteria in this study

Criteria	Participants Details
Location	Within Australia (Victoria, New South Wales, Queensland, South Australia)
Years of Experience	Between 5 years – 15 years
Type of experience	Game designing and Developing(all types of genres). Must have an experience in designing Educational games.
Types of Players' Demographic	All Demographics. Primary school players' demographics are beneficial.
Participants in the study	17

3.1.1 Data Analysis and Interpretation Approach

The interviews were audio-recorded, transcribed, and time-stamped. An initial hand-coding approach was taken before an in-depth thematic analysis using NVivo 10 software. This research adopted a six-step thematic analysis approach (Braun & Clarke, 2006, 2012), as shown in Figure 1. This analysis aims to allow the emergence of game designers' perspectives, the way they distinguish between games and EGs, their experience designing both types of gaming systems (its *growth* and *continuity*), and the way they criticize the conceptualization of games and EGs before they are designed (framing the purpose of designing games and EGs). Interpretive results are discussed through interpretivism, where hermeneutic analysis is adopted to allow game designers' experience subjectivity. Consequently, the results are rigorously discussed to demonstrate experience in designing games and EGs, what they believe games and EGs have in common, and how they distinctively describe their professional opinions. Lastly, the analysis also correlates with and is critically interpreted through researchers' epistemological and ontological positions and concepts of the theory of experience. Please note that all names mentioned in the analysis are pseudonyms[1].

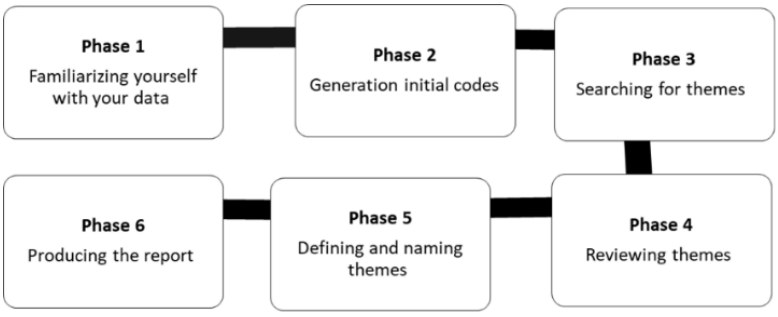


Figure 1: Steps of Thematic Analysis adopted

4. Thematic Analysis and Interpretive Results Discussion

This section centers on a discussion and interpretation of the central theme and sub-theme to demonstrate game designers' perspectives on how they value or distinguish between the term 'game' and 'EGs.' Their views must be theoretically documented to identify the necessary game design elements, features, or factors. The theme emerged from the subjective success and availing the position of game designers, designing games and EGs. It is essential to understand whether what academics and researchers publish about games and EGs aligns with game designers' perspectives. As games provide endless positive possibilities (Russo, 2021), it is critical to adhere to game designers' aspects as the first-end users who play-test the game/EGs. The validity consideration of data analysis towards the authenticity and accuracy throughout the research is achieved through techniques including triangulation (examining with theoretical concepts, investigator, and data triangulation), and peer debriefing, prolonged and persistent engagement with the raw data set to allow critical and clarity throughout the analysis and emergence of themes to be compared.

[1] Kindly note that this paper is part of a larger research project, and due to the limited number of words, the author has reduced the discussion and quotes.

4.1 Central Theme: Game Designers' views about games and Educational Games

To comprehend their beliefs and practice in designing games and EGs, game designers' experiences within their practice were highly valuable to this study. The data analysis suggested that all game designers asserted their understanding of the terms above as *"the big umbrella of games", "EGs are part of games", "some elements of games slide into EGs", and "EGs can be represented through a Venn diagram with games sharing some elements".* Consequently, most game designers (14 out of 17) did not refer/quote any specific published game designing models, frameworks, definitions, or any of the designing principles or methods/approaches. However, three game designer participants asserted that their practice of designing games considers definitions that have been formally published and prominently known in gaming research (Salen & Zimmerman, 2004; Schell, 2008; Suits, 1967).

Firstly, Bernard's definition[2] (Suits, 1967) was mentioned by **[Timothy]**, as he argued that it is 'ablative' in the sense of 'vagueness' and explained: *"it is concerning that it is so vague and can be interpreted differently by any other game designers too!"*. I observed that **[Timothy]** believes in contextualizing multiple game definitions depending on the essentialities of game requirements, and there is a *purpose* to every game concept that needs to be explored in various manners. Similarly, **[Zack]** argued: "maybe because we as game designers do not think of definitions, that is why we have failing games? However, my games have been a hit, and I define games with concepts as I go and not limit to one definition". This quote suggests that the belief of defining games is not appealing as they might feel limited to choices for the designing process.

A second definition was identified in **[Charlie's]** on Zimmerman's (2008) definition: *"I sometimes consider Zimmerman's definition of game is more simplistic. It has some direction and helps me refocus my game idea if I go broad… but other definitions exist, and they match other types of games… not for me, though".* Charlie's emphasis on allowing a refocus reconnects with the formation of purpose through *interaction* and *continuous* experiences – hence, meaningful play occurs between game and players. A third definition noted was Schell's (2008), while highlighting some crucial essential qualities for games, including playing wilfully, having goals, conflicts, rules, and winning and losing. **[Anne]** explained: *"…playing various games makes me remember how those mechanics worked and helped me achieve challenging goals. I find a playful sense through it, and that is what Schell mentions based on experiences, and I believe that is needed in every game!".* **[Anne]** values the experience of playing games as it allows her to connect with the future decisions that will affect her and her players. It also enables her to create new experiences for them after they have completed the game.

It is widely believed that most game designers do not refer to formal knowledge (definitions/published) in their practices. I observed a lack of familiarity with formally published definitions/principles and experience-based and reflective practice in the game designing field. The following section presents an interpretation of game designers' views on *balancing* between games and EGs as they share their experiences aligned with their game designing practices.

4.1.1 Views about games and educational games

This sub-theme is about the beliefs and perspectives of game designers, as they do not have a defined framework or model for describing their views on games and e-learning. Their experiences can influence their decisions when it comes to developing new experiences. Noting the plethora of literature on game designing principles, elements, definitions, and theories, fourteen (14) game designers did not mention any formally published game definition but provided an overall perspective. Additionally, observing practices, real-life choices and decisions in the designing processes were considered by game designers. The *situation* in which they make those decisions relies on their *interactions* (with the game system and within game concepts) being achieved according to the expectations (Dewey, 1938). The discussion below explores the similarities and differences based on game designers' perspectives.

For instance, I observed some commonalities in-game designers' responses. **[Nora]** mentioned: *"EGs are not too different from games because games are fun, overcoming obstacles and sharing experiences. But EGs should have the educational value where goals that needs completion refers to the learning content, I think"*. Similarly,

[2] The definition is, "*to play a game is to engage in activity directed toward bringing about a specific state of affairs, using only means permitted by specific rules, where the means permitted by the rules are more limited in scope than they would be in the absence of the rules, and where the sole reason for accepting such limitation is to make possible such activity*" (Suits, 1967, p.156).

[Terry, Max, Timothy, Raymond, Paige, Blaire, and Tia] suggested that *"fun", "challenges", "immersive", "challenging real-world environment", and "the realistic feel of design"* are crucial for all games, no matter the genre/type. Furthermore, considering the need for the design of EGs to portray realistic events, **[Max]** mentioned, *"the realistic feel through play happens through design"*, **[Raymond]** claimed *"it should not feel fake"*, and **[Paige]** asserted: *"it should be relating to something that exists but only more fictional".*

Playing games can affect engagement levels, including players' emotional and behavioral feelings. Play experiences also reconnect with intrinsic motivation theory (Malone, 1981), which includes fantasy and curiosity. A few game designers emphasized *experience*, such as **[Ross]** who added: *"that the experience of playing games is a takeaway. If learners do not experience that, no game can be educational or successful"*. **[Paige]** mentioned that: *"adding an active experience through the game tasks can help differentiate your role as a player. If the learner explores their roles, they might actively experiment! we want that!"*. On that note, **[James]** mentioned: *"as much fun as possible in-game design helps players experience exciting and curious things…EGs are not designed alongside fun, but they should be!"*. Active experimentation and experiencing the play are highly crucial, and it relatively connects with how players learn or prefer the design communicated through games. Another relevant point with experience was that EGs are somewhat similar to games, where **[Anne]**: "*there is more interactivity, engaging experience with 'educational experience' and not just an entirely fun game*". Here, defining fun is related to the emphasis on educational experience where fun may be derived through a *situation* [classroom] in which it is "richly interpretable" (Koster, 2013, p.38). Because games are defined with rules and limitations surrounding the 'fun element', which needs to be controlled when designing EGs, that becomes an insight for game designers.

As previously published work suggested, teachers desire EGs to "look good and realistic" (Ahmad, 2021). On that note, **[Joel]** emphasized: *"I think the EGs are put in its own category as 'just sh*tty games' that are not made by people trying to make it fun instead…like just 'crafting as a tool' than a fun experience."* Furthermore, **[Max]** stated: "*I think all games teach you something. But, importantly, in-game design, just teaching the player how to play the game and experience fun, is crucial! So, if I know my players' learning process, I design it to grab the fun-bit of learning without the boring-bit of learning*". It can be presumed that the *art of designing* a game depends upon the players' learning acquisition, their play preferences, and how they interact with the games/EGs. Moreover, to avoid boredom, forceful learning in cognitive learning, or how their players can learn and analyze gameplay patterns with extra details around the game world.

It was further observed that participants relied upon their intuition and *prior* play experiences in their practice and suggested another crucial point: creating experiences for the specific audience/players' psychology (cognitive development) seemed to draw a line between games and EGs prominently. I discovered similarities suggested by all game designers as they justified their answers by using players' psychology as the intended audience, age group, or cognitive development levels distinguished when designing EGs. As emphasized by **[Anne]:**

> *..we usually do not agree on a particular definition because we aim our design concepts with game ideas and players' psychology, considering engaging elements like animation that can provide meaningful choices for players/learners to take action and see how it affects the outcome.*

While it is important to adopt strategies geared toward a specific demographic group, it is also challenging to avoid overlaps from learning about the players' psychology. Instead, game designers tend to focus on the design aspects of the game through a well-defined thought process. For instance, **[Warren]** added: "*I always familiarise my understanding of how much players know and what their cognitive development level is… helps me understand how to set goals and learning outcomes in design with constraints*". They also highlighted the confusion regarding the genre mix required for EGs design. **[Terry]** advocated that: "*players love fictional, racing cars, achieving all possible challenges and competing with their friends. But EGs cannot be too fictional but require realistic interface*".

Moreover, **[Charlie]** mentioned: "*EGs need to be fictional, fun, collaborative, and also relate to the learning outcome of what the topic is…*". Considering players' psychology, game designers mentioned that players could recognize gameplays through a pattern recognition understanding of play as they immerse in many gameplays. The pattern recognition and mental conception relevant to cognitive learning seemed prominent in the discussion. The construction of gaming activities is designed in a pattern that allows players to create their

knowledge and reality based on what they experience through the play. Here, referring to the cognitive learning theory, which allows multiple paths of the game world to be exposed and players to create their mental schema (Schell 2008, p.199): *"the game is not the experience – games are simply structures that engender mental models in the mind of the player…"*.

One reasonable conclusion to the point mentioned above is to envision games as the big umbrella and EGs as falling within or a part of it. However, game designers only marginally acknowledge the differences. On this note, **[Ross]** added: "*…for me, EGs are a lot more explicit about what they are trying to get across, but they can certainly be a broad spectrum of games that have educational value"*. Moreover, **[Tia]** also emphasized: "*the learning goal or purpose that needs to be considered in designing EG was a different thing I did… it was difficult because the curriculum requirements are hard to integrate!*". Another relevant explanation is that curriculum requirements are a complex feature, as mentioned by **[Joel]**: "*I feel like most games have to teach as a system, having curriculum is the only difference added into requirement and designing phase*". **[Betty]** emphasized: "*…having fun and educational factors are difficult to work with… my team found it challenging!*". Here, addressing games directly with curriculum seems to be complex, as, despite their practice of designing games, they are still uncertain about how curriculum can be integrated with fun. All game designers in this study emphasized that EGs are designed to achieve a particular learning objective and are not designed for entertainment. For instance, **[Charlie]** asserted that an excellent learning process through play enables the development of play experiences that reflect real-world problems: "*EGs are made for learning outcomes, and it should reflect with real-world problems. That is the main difference*". The *situation* in which they [participants] experience playing relates to their *prior* experience and learning through *interactions* – is interconnected.

Three game designers revealed a clear difference between games and EGs. Their reasoning and justification for their beliefs relied upon: (1) the type of experience the players felt, as **[Tia]** quoted: "*So, it is not focused on the fun aspect, but more on the player experience information that allows a more receptive response to remembering it better*", (2) the productive outcome is combined with fun, and learning acquisition through play, as **[Blaire]** mentioned: *"…players learning outcome is productive for us when they learned and had fun which they remember and return to play the game again!*", and (3) successful learning through fun concepts within the games, as **[Raymond]** suggested: "*they [learners] typically require a significant amount of skill that you learn by playing it. Education means having a clear goal and including 21st-century skills necessary for education within design*". It also depicts that game designers rely on the experiences, unfolding the flow of their learning acquisition with the way players learn such play experiences, revealing tasks or rules in games, an experience designed as *memorable,* and how it is intertwined with *interactions*, *situational* context, and the *continuous* form of the learning process through engaging with the game world.

Understanding games as systems, **[Terry, Max, Timothy, Zack, Paige,** and **Nora]** indicated comparing both terms from a software perspective. Game designers claimed that it is crucial to express the need to have a choice-based design for players and further discussed that deconstructing how the game is designed to ensure it fits the initial criteria, along with the emotional experience desired by the players, is highly sophisticated. For instance, **[Terry]** mentioned: "*I believe that EGs are created with the express intent of delivering information to the player*". In addition, **[Zack]** added:

> *…the initial intention is to give players challenging experiences, and it's a lengthy deconstruction of the game and its criteria. Broadly, games are intended to entertain and evoke a wide array of emotional experiences... so that they [players] can absorb, retain, and use it in other contexts.*

Hence, EGs have standard content delivery expressed through the game design and allow the players to retain the content (information) when they engage with the game in a *situation* (classroom). Additionally, they immerse and connect through interaction and continuous play. Moreover, **[Nora]** defines EGs as software: "*…that has an information payload, and it uses the conventions, appearances, and experiences as the vehicle for delivery of that content and set agenda".* It suggests that it clearly relates to the formation of *purpose* by Dewey (1938) and how it drives their *desire* to *exercise their intelligence* (growth of experiences) through experimentation, and actively participating through *learning by doing* is promoted.

5. Outline of Thematic Analysis Discussion

To conceptualize the discussion, Figure 4 presents features/factors based on game designers' perspectives in Australia. It has recently been argued that games are potentially merging, and it will be more beneficial if

communication through interdisciplinary expertise is exercised (Kultima et al., 2020). Figure 4 represents a Venn diagram highlighting the intersection (co-existences) between digital games and EGs and what needs to be present as the *balance* (as labeled) according to game designers. In addition, it demonstrates that adding the factors from all digital games within the EGs design may provide higher engagement levels for learners. For example, all digital games are fun, fictional, overcome obstacles, provide shareable experiences between players, have challenging goals, and provide an immersive experience of high quality in aesthetics and design. Even so, game designers anticipate that 'players' are gamers (not specifically students or learners), and the *situation* in which players will play the game is not predefined. On the contrary, EGs need what 'all-digital games' have to establish a meaningful play experience: educational values, learning outcomes, clear goals, curriculum, and constraints as set by those curricula, avoiding book-imitation for design and aesthetics, clearly defined purpose, and instructions to allow a 'balance' between fun and learning. Game designers suggested that integrating educational values, goals, or curricula is the most challenging task in designing an EG. It is complex for their understanding to provide a perceptive or informed decision-making process of EG design.

Admittedly, game designers struggle to balance EG design between imaginative and realistic context which they believe is rewarding as players experience the stimulating experience that the game designers design. However, as agreed by (Kalmpourtzis, 2018), I observed a close relationship between *continuity* and *interaction* within the experience to allow the audience's prior experience and building experiences (*growth*) around it through a *continuous* form of play and *interaction* between the player and game (Dewey, 1938).

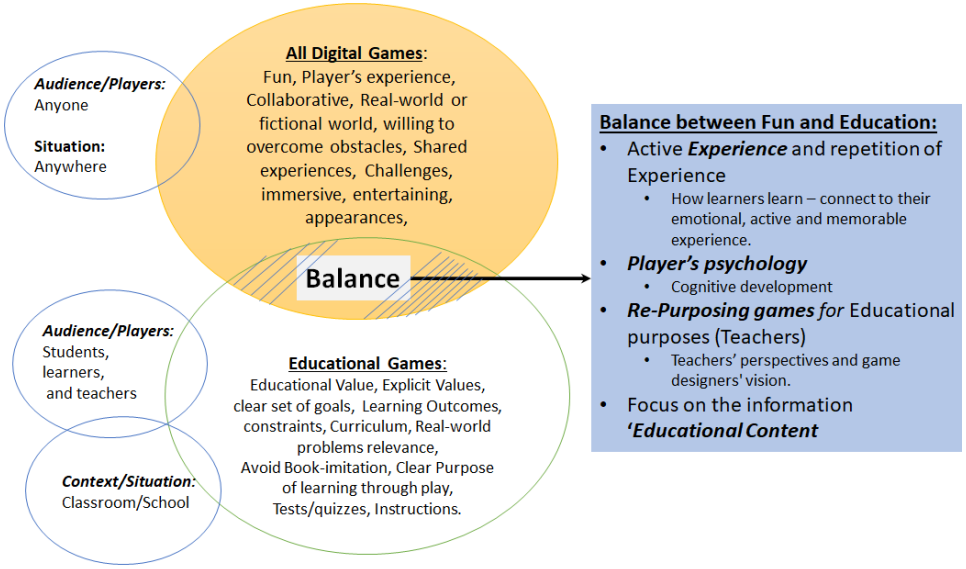


Figure 4: The intersection to demonstrate similarities and differences between games and EGs

6. Conclusion and Future work

To conclude, game designers design EGs based on their prior play experiences with versatile games and EGs. their intuitive and epistemological beliefs interfere with and impact their decision-making processes. The results suggested that game designers' practices of designing games affect their understanding when EGs are considered. Prominently, their understanding of EGs and the balance between fun and educational aspects related to a balance between active experience and repetition of experiences, player's psychology, re-purposing games for educational purposes, and focusing on educational content (curriculum requirements). The results promote a compelling need to empirically and theoretically comprehend the '*essence*' of the perspectives of game designers to decomplex the designing process of games and EGs. Addressing the EGs are subsets of games, and if EGs retain all elements of games, they may have a greater chance of success. Lastly, I observed a gap between research published on EG designing and processes/elements compared with what participants advocated. The researchers in the gaming industry need to be involved in game designers' perspectives to understand the current trends, terms used to address future frameworks/models, and how those might be reachable to the users.

Limitations include a reduction of participants due to the pandemic (2020), the number of words to represent a complete analysis, and the scope of recruitment changes. Furthermore, the data collection procedures began

with the pandemic lockdown (January 2020), which enforced re-examining of the number of participants from an initial number of 40 to 17, as saturation was achieved during analysis. Lastly, the generalization may still apply in the context of Australia and the gaming industry within Australia.

In the future, the remaining emerging themes on game designers' perspectives will be published and continue to close the gap between game designers and their perspectives on designing processes of games and EGs while valuing their experience theoretically and empirically.

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Designing a Mobile Game for Introducing Learners to a Soap Making process

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Abstract: Bunno's Fabulous Soap-Making Challenge is intended to be both, a game that is played for fun and a game from which subject content can be learned. The game is modeled on and represents authentic, real-world chemical processes. Specifically, it promotes the learning of aspects central to the soap-making process. The game is a resource-managing game in which players plan, organize, and execute the production of soap. Players source the raw materials, acquire the technical equipment, create an efficient lab setup and produce and sell soap in an economically sustainable way. The game is centrally based on the idea of constructivist learning. Players encounter an inspiring and challenging situation and are active, in control, and make their own decisions and experiences. Their actions trigger immediate responses and are consequential. The main contribution of this article is a detailed description, a conceptual explanation, and a critical discussion of the game design. In addition, this article briefly describes the educational theory which informs the project, how the game design is actually realized in the implemented game and how it can be played, and the game's educational content and the projected learning outcomes.

Keywords: chemical engineering, education, game design, learning

1. Introduction

Digital games have proven to be considerably relevant for educational and training purposes (Gordillo et al., 2022; Suzuki et al., 2021). The innate ability of games to provide active, engaging, and experiential learning environments supports their growing adoption in educational settings. Furthermore, game-based learning – the integration of learning contents into games for educational purposes, fosters the constructivist learning approach promoting personalised learning and new knowledge construction (Nino & Evans, 2015). Science, Technology, Engineering, and Mathematics (STEM) subjects have been found to benefit from games as a pedagogical tool (Hu et al., 2022; Suzuki et al., 2021). Games can potentially make the learning and retention of knowledge in these subjects more effective while improving learners' experience. This could, in turn, increase interest in STEM education.

There are, however, limitations to the number of relevant available games that enhance learning while entertaining players. Although there are many educational games available to players, there are fewer games that are relevant to STEM education. In order to take advantage of the affordances of games, particularly in STEM education, it is necessary that relevant games on different topics are readily available. An understanding of how to design games that are both fun and educating could as well increase the number of STEM games available to learners and educators.

The use of games in (formal) education has been proposed and also implemented many times (McGonigal, 2011; Gee, 2007), before and after the 'digitalisation of society or the massive economic success of computer games' (Fuchs, 2014, p.136). Various notions are associated with the idea of purposeful play. In education, Majuri et al. list "serious games, edugames or games for education, game-based learning, and lately, gamification" (2018, p.12). Many contexts and various learning practices, and different educational content have been targeted (Atmaja et al., 2020; Evangelopoulou & Xinogalos, 2018; Squire, 2006; Vargianniti & Karpouzis, 2020). Games (specifically digital games) are incredibly popular with players, and players spend much time playing them and improving their performance. The idea of educational games is here taken to be to channel some of the energy players lavishly spend on games with no or very little educationally relevant content towards games from which players can learn useful knowledge and skills. While a lot of enthusiasm appears to exist for the endeavour, and

great expectations are regularly formulated (Xi & Hamari, 2019), the purposeful exploitation of play for learning has yet met with often mixed results (Cermak-Sassenrath, 2022; Dichev & Dicheva, 2017; Koivisto & Hamari, 2019), and has also drawn a fair amount of criticism (Fizek, 2014; Raczkowski, 2014; Dichev & Dicheva, 2017; Tulloch & Randell-Moon, 2018). Many hard questions about the intricate connections between play, learning theories, and practical implementations continue to exist (Rodrigues da Silva et al., 2019). This paper describes the design of a digital game that teaches the principles of soap making to learners. It is not only a fun game but one that mimics the actual scientific process of soap making while incorporating other activities in the supply chain.

Bunno's Fabulous Soap-Making Challenge (Figure 1) is a mobile game designed to teach soap-making to players. It is intended to be a game that is played for fun and a game from which subject content can be learned (Cobb, 2007). The game facilitates an engaging and challenging activity that is modeled on and represents authentic and accurate real-world chemical processes. Specifically, the game promotes learning about the soap-making process.



Figure 1: The game's menu screen

The main contribution of this article is a detailed description, a conceptual explanation, and a critical discussion of the game design. In addition, this article briefly describes the educational theory which informs the project, how the game design is actually realized in the game prototype, and how it can be played. Finally, the game's educational content and the projected learning outcomes are summarized.

2. Educational theory

A constructivist educational perspective informs the design of the game. Constructivist learning theory considers learners to be knowledge creators; learners actively construct their own subjective mental representation of reality by linking new information to prior knowledge (Wu et al., 2012). Games provide active learning environments that promote experimentation while enhancing higher-level knowledge construction. This game empowers learners to learn by doing, creating new experiences, and applying previous knowledge. The situation requires the skillful intervention of the players and incentivizes participation and explorative processes of investigation. The subject content becomes meaningful because it is needed and used in context, with observable and relevant in-game consequences. This is taken to be an effective and engaging way to learn that also promotes the practical application of the learned content.

3. Game design

The game design is based on the idea of facilitating, for the players, a hands-on and highly interactive experience of the chemical process and of several of its essential properties. For instance, the players acquire materials, operate equipment, and move substances from one step to another. The players' actions trigger appropriate, dynamic responses, for instance, when heating substances. All actions of the player and responses from the game are supported by rich, multi-sensory feedback in the form of graphics, animations, and sounds. The interaction with the items and mechanics of the game provides direct and immediate feedback, naturally and tightly integrated with the process at hand. For instance, useful actions such as filling water or lye into a pot (by dragging and dropping on-screen items) are intuitively supported by graphical highlighting and audio feedback;

other actions have feedback that signals that they are not useful, e.g., the dragged item is being moved back, and an audio sound signals error (very brief, textual hints are also given in a few in-game situations, such as when starting the game for the first time). The way players learn about the in-game activities is similar to how players learn to play entertainment game titles; in an exploratory, emerging, and spontaneous process, not by following orders or a plan made ahead of the interaction (Charsky & Ressler, 2011). The resulting experience should support an intuitive understanding of the processes based on players' own observations and immediate experiences.

Decisions have been made with regard to scoping the game content and the level of detail. The game is clearly selective in its representation of actual chemical processes. The content is simplified in at least three dimensions: First, a decision for one specific chemical process to create soap has been made. Secondly, the range of available equipment and raw materials in the game has been limited. Thirdly, the properties of the items in the game have been simplified and abstracted (for instance, heaters do not use any fuel that would need to be supplied, materials do not need to be transported, vessels do not fall over, and chemical reactions are sped up). The world surrounding the game is outlined only; delivery times, e.g., of materials, taxes, hiring of workers and variable prices, and many other aspects are omitted.

There is a tradeoff between accuracy and playability; the focus of the game is on playability, and this produces some inconsistencies. For instance, the intermediate product (trace) that is created during the soap-making process is not buyable in the shop. It can be argued both ways: it should be buyable because it is a shop, and all other in-game items can be bought and sold there; on the other hand, the point of the game is to make soap, and not only to trade items. Having trace not offered in the shop sends a clear message to players that the way to produce soap is by initiating the chemical process with all intermediate products. Usually, such inconsistencies are tacitly tolerated by players.

The game design strives to use only a few parts but to facilitate a high level of integration of these parts with each other. The game is easy to start and has only a few objects and activities, but the behavior and interaction between the parts are complex and emergent. For instance, players need to decide when to switch from a small-scale production process to larger batch sizes with more advanced (and expensive) equipment.

Although typically, casual games avoid text and use mainly graphics, this game does use text labels for all items in the game combined with iconographic imagery (e.g., for the materials). This makes the game accessible and easy to play and, at the same time, communicates correct designations to players. All feedback is given directly and naturally through game play, not, for instance, through text in pop-up dialog boxes.

The game should not only incentivize players to learn about the soap-making process but also enable them to learn about it by trying out *how to make soap*. The game is suggestive of many of the activities that lead to the successful production of soap and of the needed materials and equipment. For instance, by providing the player with an in-game currency and a shop with items, it should be rather clear to players that buying items is part of the game. Equipment such as heaters and pots have obvious functions that align with everyday experiences players have. The different categories of items available give hints, as well: For instance, equipment is provided in various sizes or qualities; in-line with experiences from other games, it might make sense to start with the smallest and cheapest option. All raw materials included in the game are probably needed to make soap; they are packaged in the correct package sizes for one batch of soap. The heaters and pots show small icons of the needed materials that need to be added for the process to start (Figure 2).

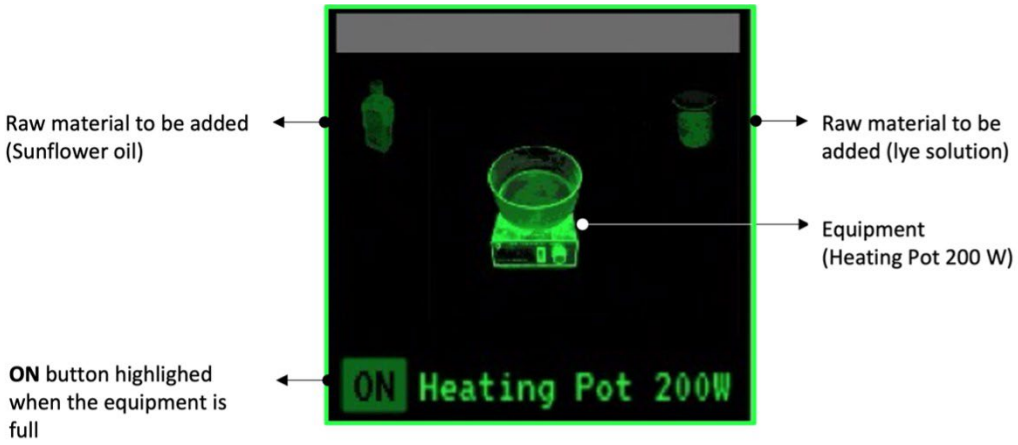


Figure 2: The user needs one unit of sunflower oil and one unit of lye solution to fill the heating pot of 200W

There are several items in the shop that are obviously unrelated to the soap-making process and are rather expensive, such as bubble bottles, ponds, matches, crayons, etc. (Figure 3). There is no information provided, and it is unclear to players what in-game effects they have (if any). These items are included in the game for two reasons: (1) To give players something to strive for. The items are not needed to play or win the game, so they constitute luxury goods. The items stand for achievements, and by acquiring them, players can reward themselves for succeeding in the game. Having acquired a particularly hard to get item might also serve as basis for bragging about it, for instance, towards friends also playing the game[1]. (2) The items may have hidden or unknown in-game effects. There are no explanations what these items do in the game, or what they can be used for, so players may be curious (or surprised) to find out. We are also not disclosing the effects here, so the only way to find out if the items do anything, or what they do, is to play the game, and to play it well.

The game does not include an end condition, such as number of coins earned or kilogramme of soap produced. As a resource-managing game, there are constantly opportunities for the optimization of the in-game processes. The players decide when to stop playing. We expect three scenarios for situations when players stop playing the game: (1) They fail to set up an economically sustainable production and run out of money; effectively, the game does end in such a situation, because players cannot act anymore. (2) They have acquired most or all of the bonus items and feel they have succeeded in beating the game. (3) They have mastered the game, and were successful in establishing a well-working system of soap production. Of course, players may continue to play the game after they have beaten it and enjoy their mastery of it. Also, it is a rather common practice that players chose to play a game they have already won multiple times in different ways. For instance, they might try to play the game while using only a subset of the available equipment; or they might speedrun the game, and see how fast they can make 1000 coins or similar.



Figure 3: Examples of items unrelated to the soap-making process[2].

4. The game

The game is a digital, single player, resource-managing game. During game play, players plan, organize and initiate the soap-making process and control and manage it over time. Players also need to be aware of economic

[1] Note that this is a different approach than trophies or rewards such as medals which as handed out to players in gamification initiatives.

[2] The items' images were modified and obtained from freepng.fr, maxpixel.net, toppng.com, and pngfind.com.

aspects of the endeavor, such as questions of efficiency and capacity utilization, and to keep the equipment upgraded in-sync with the (increasing) scale of the manufacturing process.

Structurally, the game consists of two complementary parts; one part in which infrastructure is built up (bought, arranged, sold), and one part where this infrastructure is used (to manufacture soap). Both parts enable and rely on each other; the infrastructure enables the manufacture of soap, and through the manufacture of soap, money is earned to sustain the infrastructure. In the lab, players arrange equipment, store raw materials, and start and manage the chemical process (Figure 4a); in the shop, players acquire the needed items and also sell the product (Figure 4b).



a) b)

Figure 4: Game screens: a) The lab with materials and equipment; b) The in-game shop

The game should be popular with players and compete with similar games. It thus runs on multiple gaming platforms and is released as a free game through established online channels for the distribution of commercial or indie casual games, such as the Google *Play Store*.

A typical playthrough of the game could be similar to this: The player starts with an empty lab and 250 coins. The player clicks on the shop button and enters the shop. In the shop, the player clicks on the buy button and selects (left-click) the small heating pot (200W), 500 ml of lye solution, and 4 kg of sunflower oil. The player goes back to the lab. In the lab, all the bought items have been placed in the available grid position. The player then drops all the ingredients into the pot, one by one. The player checks that all the required ingredients are present and also in the needed quantities. The player then switches the heater on and waits for the pot to reach the required temperature (the player checks the temperature progress bar on top of the heating pot). Flames rise from the pot to signal that the trace is ready, and the heater is switched off automatically. After the process is completed, the trace appears in the first empty space on the grid. The player realises that more tools are needed to finish the process, goes to the shop and buys a curing form. The player returns to the lab and drops the trace into it. But then, the player realizes that fragrance and colorant are also missing, so returns to the shop. The player returns to the lab and drops the rest of the raw materials into the curing form. After several minutes, a batch of 6 kg of solid soap appears in the grid, and the curing form is again available for more traces to be created. The player goes to the shop; in the shop, there is now a batch of soap that can be sold. The player makes the sale and is delighted by a rewarding sound. The player invests the money earned in new raw materials and later, after a few days of playing, into upgraded equipment. The player also optimizes the flow of the operations, so there are fewer waiting times, and there is always cash available (e.g., by having more than one batch of soap in (overlapping) production).

5. Projected learning outcomes

The game's educational content is the chemical process of making soap, specifically the kettle process (Preston, 1940). Learning in this game happens on multiple levels: On a basic level, players learn about the various materials and equipment used in the process (such as visual appearances, names, and functions). At the same time, the order of operations in several steps for the soap-making process emerges (e.g., heating the materials, then curing, and finally producing soap, Figure 5). At last, complex patterns of dynamic interactions appear, for instance, when aligning the upgrading of the needed equipment over time with the increase in soap batch sizes.



Figure 5: The process as represented in the game: Saponification of the raw materials in a heater, curing, mixing, and cooling of the trace; the finished product (soap)

Educational content is the process of soap making which involves a chemical process and reaction. The game aims to emphasize the usefulness and essential role of chemistry in everyday life by using a common product and process.

The game simplifies the *chemical process* into two main steps: creating a trace and curing the trace to produce soap. The process is inspired by the *kettle process* typically used by small soap producers (Preston, 1940). Additionally, there are different elements related to the process which can be learned from the game. For instance, ingredients, amounts of substances, the time needed for reactions, steps involved in the chemical reaction, effects of, e.g., heating on substances, equipment, and machines involved, issues of scaling of chemical production from individual batches to mass production.

The game simplifies the *chemical transformation* (saponification reaction) in the first step. The player learns that when sunflower oil and lye solutions are mixed at high temperatures, the trace (soap) is formed. To finalize the product, the players realize that the trace needs to be *cured* for a specific time and mixed with certain ingredients to make the final product (colored, scented soap).

6. Conclusion

The main contribution of the article was a detailed description, a conceptual explanation, and a critical discussion of the design of a mobile game that contains educational content. In addition, the article briefly described the educational theory which informs the project, how the game design is actually realized in the implemented game and how it can be played, and the game's educational content and the projected learning outcomes.

Bunno's Fabulous Soap-Making Challenge is intended to be a game that players play for fun and a game from which they can learn subject content. Informed by constructivist learning theory, the game promotes knowledge construction through active experimentation in the game: Players encounter an inspiring and challenging situation and are active, in control, and make their own decisions and experiences. Their actions trigger immediate responses and are consequential.

The game is modeled on and represents authentic, real-world chemical processes. Specifically, it promotes the learning of aspects central to the soap-making process. Moreover, the learning content emphasizes chemistry's usefulness and essential role in everyday life, which can serve as a basis for interest development in STEM subjects. The game is a resource-managing game in which players plan, organize, and execute the production of soap. Players source the raw materials, acquire the technical equipment, create an efficient lab setup and produce and sell soap in an economically sustainable way.

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Development and use of a Playful Learning Observation Tool (PLOT) for Active Game-based Learning in Physical Classroom Situations

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Abstract: Purpose – This study presents the development and implementation of a qualitative observation tool for in-class observation of courses employing game-based learning (GBL), and playful learning situations. Methodology – The design of the observation model exploits a literature review of classroom observation models, of cognitive psychology motivation scales, and of GBL evaluation models. It integrates relevant elements from these domains to offer an observation model for GBL implementation. In this model, in-class observations are coded and analysed for GBL effectiveness and potential to support intrinsic motivation in students. The model was then used in two courses using different forms of GBL (one digital cooperative multiplayer game, one analog board game). Observations were coded using NVivo and distributed according to type of motivation and type of motivated learning tasks. Due to Covid19 restrictions and the difficulties of finding in-person classes, only two courses were examined using the model. Findings – the model appeared efficient in both observational situations, and the coding confirmed previous studies to the potential of GBL to sustain students' intrinsic motivation. The observations also showed that preparedness of students to the specific contents of the game reduced risk of amotivation and disengagement in students. Practical implication – The study allows us to reflect on best practices for GBL implementation and evaluation and how better understanding of in-class interactions during playful learning could enable educators and teachers to make better informed choices to implementing GBL. Interest – While there are many templates for classroom observation and GBL evaluation, there is a lack of dedicated observation models, that offer clear guidelines for qualitative data gathering in live, in-person classroom situations. This study aims at providing a specific tool to that purpose.

Keywords: game-based learning, qualitative data, observation, evaluation tool, motivation

1. Introduction

Using games and simulations in education is a common approach to increase quality of study through active learning. Active learning enables students with 21st century skills such as learning and innovation skills, media and technology proficiency and lifelong learning capacity (Soranastaporn et al., 2017). Several meta-studies have pointed to the effectiveness of games for cognitive, affective, and psychomotor learning (Sauvé, 2010). There is currently sustained interest in the field of playful learning,

However, evaluation of curriculums integrating game-based learning (GBL) has proved challenging owing to the wide range of technical, material, and human components that intervene in playful learning. Effectiveness of GBL has often been questioned due to this difficulty, but over the past decades empirical research has solidified interest in the playful learning approach, a recently coined umbrella term that tries to encompass various approaches, from gamification to digital GBL, educational escape games, board games and roleplaying games (Whitton, 2018). Common evaluation practices include students' performances through grades, pass rates, knowledge in pre- and post-tests, as well as students' perception of the learning process, through their self-reported appreciation of the method, interest in the studied subject, and evaluation of the technology. (Algayres et Triantafyllou, 2019). To fully understand the application and elements of GBL, though, prolonged time and extensive observation are necessary for gaining an in-depth understanding of a classroom proceedings. This task necessitates qualitative methodology (Fasse and Kolodner, 2013).

Classroom observation has always been part of the qualitative methodology toolbox. It has yet always seemed to play an auxiliary role to other methods such as interviews or text analysis. Among the challenges that Classroom observation presents many challenges (time, organization, ethics, impact of the researcher's physical presence on the teaching process), especially in finding a relevant model to frame the observation and get a clear understanding of what is happening in the classroom. It appears that there is a lack of observation models for GBL in the classroom.

Indeed, there are many teaching observation models (American Association for the Advancement of Science, 2013), as well as models to evaluate serious games efficiency for engagement and educational purposes. GBL

has often been studied through comprehensive methods of evaluation (e.g., Emmerich et Bockholt, 2016), but few or no models are specifically dedicated to observation of GBL in the classroom.

In this article, we try to bring an answer to this issue by designing PLOT (Playful Learning Observation Tool), a scale and analysis model for implementing GBL in physical classrooms. Our objective will be 1) to determine how we can build an observation tool for GBL in the classroom focusing on student motivation to participate in the learning process, and 2) if we can implement this tool in different classroom situations with different types of games. The structure of the article is as follows: we will present the literature background, the methodology for the design of the tool, the implementation of the tool, the results of the observations, and discuss the potential and limitation of our tool.

2. Background literature

We approached this study by examining the main topics relevant to the design of a GBL observation tool: classroom observation tools, GBL evaluation patterns, and student motivation models. We reviewed each topic to identify the most relevant elements to build our dedicated observation tool.

2.1 Classroom observation tools

Our first element of inquiry was classroom observation tools. While it was not possible to make an exhaustive recension of such tools, we investigated various examples both from manuals on qualitative data and case studies of observation tools development.

The objective of an observation tool is to support fieldwork research, which necessitates both long-term participation in a field setting, "careful recording" of what happens and "subsequent analytic reflection on the documentary record" (Erickson, 1985). Erickson (1985) thus recommends looking into specific structure of occurrences, and the way they can illustrate perspectives of specific actors for specific contexts. Wragg (2012) introduces a similar point through the critical event technique, with the idea that "the observer looks for specific instances of classroom behaviour which are judged to be illustrative of some salient aspect of the teachers' style or strategies: an element of class management, for example, a rule being established, followed or being broken". The American Association for the Advancement of Science (2013) published an extensive documentation focused on describing and measuring teaching practices in STEM. They recommend distinguishing descriptive and evaluative perspective (the first one centered around as objective as possible reporting, and the second trying to pin it against best practices or models). They also present several use cases of classroom observation tools.

With these points in mind, we analysed several observation tools. The results of this analysis can be read in table 1.

These case studies shared some elements that guided us for our own design and implementation. First, they would clearly identify the object of the observation, whether focusing on teacher, students, interactions between any of the two, engagement in each activity or manifest signs of engagement (e.g., questioning, sustained interactions). Secondly, they would provide a detailed list of relevant items to observe so that the tool could be applicable even in situations where the observer is not knowledgeable in the curriculum. Finally, all case studies acknowledged the limits and challenges of observation while trying to answer these issues. A very relevant point is that observation alone can be limited by lack of training in a designated model, by the nature of what is or is not observable, and the given number of sessions (AAAS, 2013). Therefore, while we focus in this paper on a designated model, we underline that qualitative observation should always be used in conjunction with other data, such as surveys or assessments (Holbrook, Gray and Fasse, 1999), or with other qualitative data taken from text documentation and interviews.

Table 1: Summary of classroom observation tools

Name of model	Focus of observation	Items described	Reference
PORTAAL Practical Observation Rubric to Assess Active Learning	Teacher and student behaviour	Four dimensions with focus on teacher's implementation on good practices (practice, logic development, accountability, reducing student apprehension). Some observations on students' engaging with teachers, manifesting support to their peers	Eddy, Converse and Wenderoth, 2015
Teacher–Pupil Observation Tool (T-POT)	Student and teacher interactions	Teacher-child and child-child interactions, coded for positive and negative interactions	Martin et al., 2010
STROBE Classroom Observation Tool	Student behaviour and engagement	Description of activity, proportion of active students, learners' behaviour (listening, writing), direction of attention	Adam Kelly et al., 2005
Flanders Interaction Analysis System (FIAS)	Student behaviour and engagement	Affect, engagement, and misbehaviours during class	Yang and Moskovsky, 2021
Observation Tool of Active Gaming and Movement (OTGAM)	Children's movements (strike, throw, roll)	Items describing children movement and activity (On/Off) engaged/disengaged	Rosa, Ridgers and Barnett, 2013
Observational Prompt Tool (OPT)	Students' activities and behaviours in class	Detailed activities or specific goals showing engagement (generating questions, group collaboration)	Holbrook, Gray and Fasse, 1999

Our objective in designing an observation tool is therefore threefold:

- A tool for a defined element, here interactions during the GBL experience.
- A tool presented as a list of items relevant to GBL.
- A tool that would enable both descriptive and evaluative perspective and be accessible even to observers with no GBL experience.

2.2 GBL evaluation tools

Our second main topic regards GBL efficiency in terms of student engagement, and evaluation grids to measure it. Integration of game mechanics (or *gamification*) has been typically used to enhance the teaching-learning process through the improvement of the students' motivation (Klock, Gasparini, and Pimenta, 2019). Similarly, GBL aims to stimulate motivation and problem-solving skills in learners by integrating learning materials into the gameplay (Tao, Huang et Tsai, 2016).

We examined several models of GBL evaluation tools, and how they defined categories to frame the user experience. Not all categories apply to in-class observation, but they provide guidance to the elements to examine in physical classrooms situations. The approach by Oprins et al. (2015) followed a linear temporal structure based on input, process, and output. Process includes game design, motivational and cognitive elements, and output focuses on learning objectives and outcomes (Oprins et al., 2015). Klock and Pimenta (2019) developed the 5W2H framework by focusing on material implementation of gamification, under the thematic question marks who, what, why, when, how, where, and how much. These categories cover a wide range of elements from type of players to interactions, playing goals, type of interface and educational outcomes. Similarly, Aubert, Medema, and Wals (2019) proposed a model based on three poles of evaluation: game design and technical aspects, people and processes, and purpose and outcomes. Tahir et al. (2018) presented in their model six parameters for evaluation: learning/pedagogical, game factors, affective cognitive reactions, usability, user, environment. Finally, in perhaps the most comprehensive analysis, Sanchez (2013) determined seven key criteria for game design, three motivational (based on competence, autonomy, and relatedness), as well as content, rules and feedback, mistakes and emotional aspects, and game integration.

We derived from this analysis the necessity to integrate in our model both elements of game design, user experiences and affects, as well as the connection to the importance of motivation in GBL experiences.

2.3 Motivation scales

Finally, we researched specific motivation scales. Indeed, for our model to be both descriptive and evaluative, we wanted to connect classroom observation with the potential to support motivation in students. Previous research has indicated that educational games have the potential to sustain motivation in students (Algayres, 2019).

The development of the model thus relied on fundamental principles in active pedagogies and students' motivation in cognitive psychology. Viau (1997) established three aspects in students' motivation: a sense of competence, an understanding the finality of the learning task, and control of the activity. Self-determination theory (SDT) as formulated by Deci et Ryan (1985) established both a continuum of motivation, as well as the idea that self-determined motivation depends on the satisfaction of three fundamental psychological needs: need of autonomy, need of competence, need of relatedness. These fundamentals have been reprised in many studies on GBL and active learning such as Minnaert and Boekarts (2007) or Sanchez (2013). Deci and Ryan (2000) further establish intrinsic motivation as "the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn (…) The construct of intrinsic motivation describes this natural inclination toward assimilation, mastery, spontaneous interest, and exploration that is so essential to cognitive and social development". Figure 1 presents a synthesis of SDT used for our model.

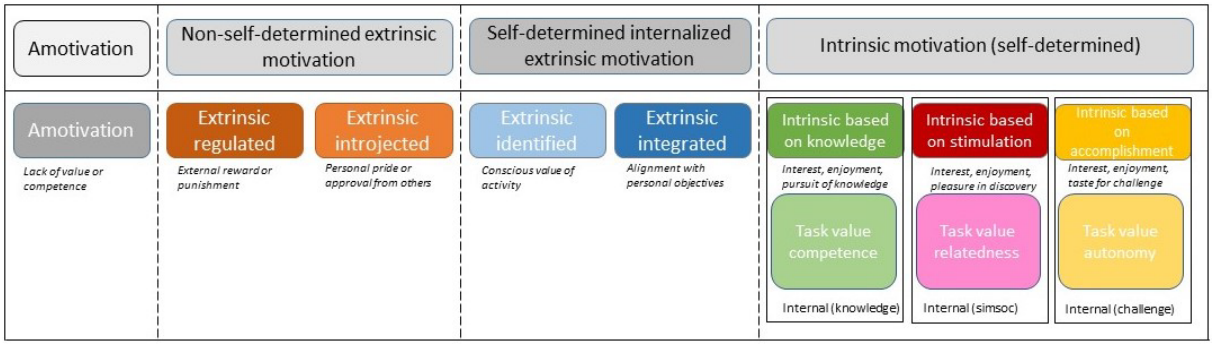


Figure 1: Synthetic representation of motivational constructs

This figure represents the continuum of motivation as well as the three fundamental psychological needs assigned to the task value. We distinguish in this repartition:

- amotivation (complete lack of value)
- non-self-determined extrinsic motivation (regrouping regulated and introjected extrinsic motivation, covering external factors from rewards, punishment to peer or teacher approval)
- self-determined internalized extrinsic motivation (grouping identified and integrated extrinsic motivation, situations where the task is not enjoyable but aligns with the students' perception of its value or align with their interests, in obtaining a degree in their chosen field for example)
- intrinsic motivation which, based on interest, enjoyment, and inherent sense accomplishment, is the most desirable to ensure long-term positive educational outcomes. Intrinsic motivation has three subcategories which we have tied to specific task values and fundamental needs. We grouped sense of competence with intrinsic value based on knowledge in the internal (knowledge) category. The internal (simsoc for stimulation and social) category groups motivation based on stimulation and need for relatedness. Finally, the intrinsic motivation based on accomplishment and need for autonomy for the internal (challenge) category.

3. Methodology

3.1 Design of the Playful Learning Observation Tool (PLOT) and analysis scale

From the elements studied in the literature review, we devised the PLOT tables and scales. The most prominent influences in this design were from:

- Holbrook, Gray and Fasse (1999) observation prompt tool, due to the clarity of their item list and focus on active learning through their Learning by Design methodology,
- Deci and Ryan (1985) self-determination theory and motivation scale, and
- Sanchez (2013) key criteria for game design as well as Klock and Pimenta (2019) 5W2H framework.

The PLOT table is comprised of two parts: the first part records the practical information of the course observed (date, place, number of students, subject), as well material conditions of the course (physical and social environment, type of learning tasks, discipline), while the second part, the PLOT table, focuses on the GBL experience. We decided to present this table under the appellation "playful learning" since its focus is on practical activities and interactions over the course of a GBL session, whatever the type of game considered.

The PLOT table lists 51 items regrouped in four categories: Who? (Players' profile, preferences, game culture), What? (Tasks, interface, communication, performance), Why? (Fun, engagement (cognitive, behavioural, emotional), play dynamics), and How? (Mechanics, dynamics, components, player journey, reinforcement). Each item takes the form of closed statements that leads to a yes/no perception, allowing the observer to simply list what happens (or not) during each playful learning session. Examples of such statements are, e.g., "Students play in teams"; "Students have a clear victory goal"; "Students make active use of their knowledge during the game"; "Students get immediate feedback from the game", but also negative outcomes such as "Some Students appear uninterested and disengaged"; "Some Students ignore the rules or cheat". Figure 2 shows the table in its original form.

Question	Who?	What?
Focus	*Players' profile, preferences, game culture*	*Tasks, interaction (interface), communication forms, performance (evaluation)*
Notes	• Most S have experience playing similar games • Most S have no or little game experience • S play solo • S play in teams • S play as themselves • S are given a specific role (alibi) • S prepared for the game before the session • S went through the game session on the spot • Some S express discomfort with GBL	• The game has been designed for a specific curriculum • S have a specific and functioning interface/material • Problems with the interface/material (explain _____) • S communicate directly with each other during the game session • S communicate online during the game session • S have a clear victory goal • S are given a loose set of objectives • S get a specific summative evaluation after the game • S participation in the game is not evaluated • S understand easily the objectives and tasks of the game • S self-regulate their progression objectives • S require a lot of T guidance to get started with the game • T frequently intervenes to reframe the game experience • S express frustration with the difficulty of the game tasks

Question	Why?	How?
Focus	*Fun, engagement (cognitive, behavioral, emotional), play dynamics*	*Mechanics, dynamics, components, player journey, reinforcement*
Notes	• S accomplish clearly identified challenges/tasks • S accomplish tasks that have equivalences IRL • S follow the game rules to accomplish their objectives • S make active use of their knowledge during the game • S can interact within a simulation of a different context • S follow a specific narrative • S engage in discussion often, pleasantly and/or humorously • S can change their objectives during the game session • S appear active and engaged • Some S engage only when actively solicited (by T or other S) • Some S appear uninterested and disengaged • Some S ignore the rules or cheat • Some S actively voice discontent with the game	• S engage in collaborative play • S engage in competitive play • S hear the learning objectives clearly (T or material or interface) • S show clear understanding of the mechanics and progression • S "level up" over the course of the game • S know their score and/or level at all times • S can see their level compared to others • S get immediate feedback from the game • S get a reward after each action/objective • S have possibilities of retry and error • S can customize their character/avatar • S can advance/influence the story/narrative during the game • S can support each other during the game • S get a debrief session after the game • S manifest low motivation and/or disengagement

Figure 2: Excerpt of the PLOT table

Each item of the PLOT table was listed in a dedicated analysis table and coded according to the motivational elements presented in Figure 1. These elements were listed both in Excel and NVivo. The choice of NVivo as a coding tool was made because of its speed and reliability, and easy to code nodes (i.e., codes that ensure monitoring of what is being observed. NVivo as a software tool has proven its efficiency to process data from various sources, among others classroom observations and field notes (Ozkan, 2004).

This structure allows the PLOT table to be used first for descriptive purposes, listing elements of interactions that can be easily observed even by observers without gaming experience. The PLOT analysis scale allows for an evaluative observation, by assessing which motivational elements are the most present in the observed experience. We express these elements in percentages of the total of items observed to evaluate the relative weight of each motivational construct.

3.2 Implementation

We tested the model in two different courses, for two different games, over four play sessions each. Table 2 presents the main characteristics of each game.

Table 2: Summary of games used in the study

Game	Type of game	Level	Number of students	Student per playing teams	Main game mechanic
Game 1	Digital multiplayer quiz	Undergraduate	10-12	2 students	Players team up to answer questions
Game 2	Non-digital strategic boardgame	High School	12	4 students	Players win tokens by performing learning tasks that they can spend on the game board

The first course involved undergraduate students in Aalborg University, Denmark, enrolled in the Medialogy curriculum, during a course entitled "programming of complex software systems". Since the course was delivered in a hybrid format due to partial resuming of classes after the Covid lockdown, only a group of 12 students took part in the game sessions. Game 1 was a multiplayer digital quiz like the one found in the popular educational application Quizlet: students are paired randomly, one student gets a series of questions while the other gats a set of responses, and they need to work together to pair the correct question and answer. Figure 3 presents a screen capture from the players' dashboards in this game, and a picture of the students sitting in playing pairs in the classroom. The students moved to sit in pairs or in small groups formed of several player teams. However, the classroom configuration did not allow for much flexibility.



Figure 3: Dashboard and classroom configuration for Game 1

The second course involved a group of 12 students at high school level (grade 10) enrolled in Østerskov Efterskole during Danish language and History lessons. Østerskov Efterskole is boarding school in Denmark where the entire process of learning revolves around GBL. A new game is designed and played by students each week, and courses are organized around the theme of that game. This method has been studied by Gjedde (2013) who concluded that students were highly motivated by GBL, and their results were equal, if not superior for some special needs students, to those of their peers in the same age group. We observed four classes based on a game entitled "Peace in our time". Game 2 was a board game where groups of four students would represent fictional countries engaged in diplomatic strife. As students do more conventional learning tasks

(worksheets, group discussions), they earn resources that can be spend for the progression of their nation on the game board. Figure 4 presents the boardgame and students during a play session.



Figure 4: Board game and classroom configuration for Game 2. Some students regroup around the boardgame table while others are busy at their learning tasks.

For each of these two games we ran four observation sessions. Each class was observed during 90 minutes under teacher supervision. The undergraduate students in Game 1 also had an autonomous group working time that was not observed. Due to COVID-19 restrictions there was only one observer, who noted items through all the session, and revised the whole grid at the end of each session.. We believe that a two-observer framework, if possible, would improve the accuracy of observation. Since items in the model describe general behaviours in the playful learning experience, they are only listed once per session, regardless of how many occurrences happen in a single session. We ended up with a total of 71 items for Game 1, 74 items for Game 2, and coded them both in Excel and NVivo.

4. Results

We sorted our list of observed items based on motivational constructs both in Excel and NVivo. The data can be both read as number of occurrences per item, and items listed by session. Each game was then evaluated with the number of items for each motivational construct in proportion of the total. Figure 5 presents an excerpt of the coded table in NVivo.

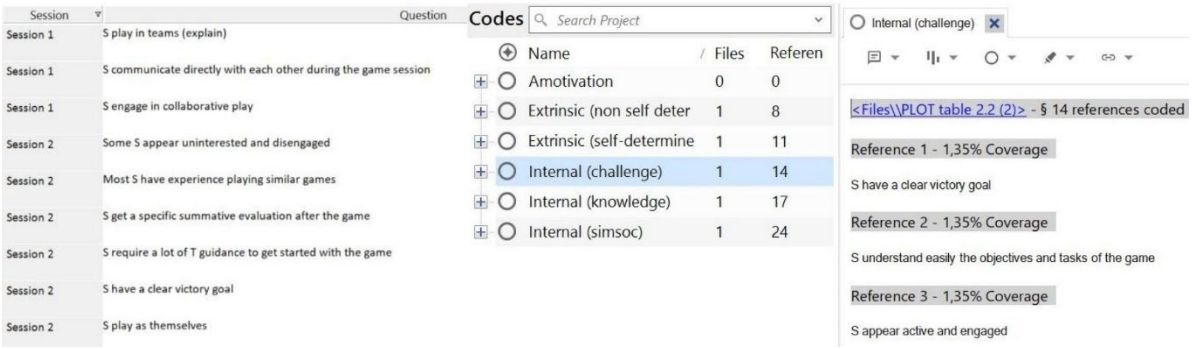


Figure 5: Excerpts of the coded table. Each item is listed by its code in the initial list, by session observed and by motivational construct associated with it.

Table 3 presents the item score and percentage for each construct and each game. Figure 5 presents the visualization of this data for game 1 and game 2. This allows for an easy descriptive and evaluative photography of each game session.

Table 3: List of motivational constructs and proportion of total for each label

	Intrinsic (knowledge)		Intrinsic (simsoc)		Intrinsic (challenge)		Extrinsic (SD)	Extrinsic (NSD)		Amo
Category	IMK	TVC	IMS	TVR	IMA	TVA	Einter	Eintr	Ereg	AMO
Items Game 1	7	4	4	12	15	10	6	0	8	5
Percentage Game 1	9,86	5,63	5,63	16,90	21,13	14,08	8,45	0,00	11,27	7,04
Items Game 2	6	11	11	13	6	8	11	7	1	0
Percentage Game 2	8,11	14,86	14,86	17,57	8,11	10,81	14,86	9,46	1,35	0,00

Definitions: IMK: intrinsic motivation based on knowledge; TVC: task value based on competence; IMS: intrinsic motivation based on stimulation; TVR: task value based on relatedness; IMA: intrinsic motivation based on accomplishment; TVA: task value based on autonomy; Einter: extrinsic motivation internalized; Eintr: extrinsic motivation introjected; Ereg: extrinsic motivation regulated; SD: self-determined; NSD: non-self-determined; AMO: amotivation.

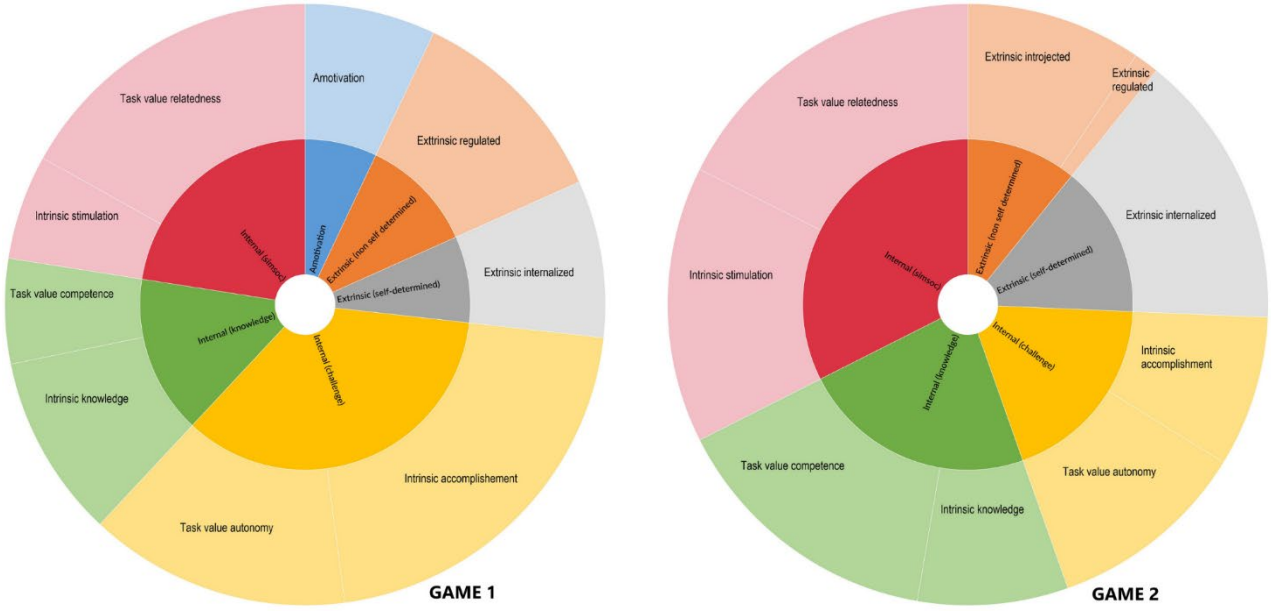


Figure 6: Pie charts for Game 1 and Game 2 sorted by categories and motivational constructs

The scores and visualization in terms of motivational constructs on both games are consistent with previous research (Algayres, 2019) that indicates that GBL can support intrinsic motivation in students. In our early research in GBL, the tested roleplaying game had shown improvement in intrinsic motivation based on stimulation and accomplishment. Game 1 presents its most salient features in the intrinsic (challenge) category, with high representation of accomplishment and task value autonomy, and scores also high in task value relatedness. This is consistent with the game being a multiplayer quiz, played in total autonomy, focusing on straightforward testing of knowledge with an immediate and quick victory goal, and necessitating a lot of student interaction. On the other hand, Game 1 presents higher scores in regulated extrinsic motivation and amotivation, which aligned with observations of a game that needed more teacher coaching to start, and where some students appeared averse to the GBL approach, and some did not prepare before class.

In comparison, Game 2 presents its higher features in intrinsic motivation based on stimulation and relatedness, as well as task value based on competence. This is also consistent with a game that emphasized group identities with students building their own fictional nation and flags and earning victory points doing learning tasks. The approach for the game was more holistic, leading in better motivational points for stimulation. Furthermore, Game 2 presents a significant score in internalized (self-determined) extrinsic motivation. This is also consistent with a student group, where GBL has been fully integrated as a valid method of education since it is part of their daily routine, and with students who were better prepared for the game.

5. Discussion

We observed that we managed to conduct observation sessions with our model for two very different type of games. By focusing on student-student and student-teacher interactions, as well as specific gameplay dynamics, the model could be applied to both groups equally. The repartition of the observable items in four delimited categories also made it easy to fill out. We consider that the observation model could easily be applicable in other curriculums or modes of GBL. The PLOT table and scale has therefore the potential to be an easily usable and replicable tool, to map both the student and teacher experience in a GBL situation, and to determine which motivational constructs are at play.

However, there are clear limitations to this approach. The first one is that due to ongoing Covid-19 limitations in terms of class reopening and external contact, we could only test our model with two games with a single observer in the room. More testing will be necessary to establish its pertinence in the long term. Furthermore, as stated earlier we strongly consider that observation is but one tool and aligned with Yazan (2015), we consider that qualitative data deriving from class observation should always be used in conjunction with other methods, both qualitative (interviews, textual and photographic analysis), and quantitative (surveys). However, owing to our initial purpose of trying to remedy the secondary role and poor documentation of classroom observation, we believe our tool to be appropriate to try and support valid and quality observation sessions in the classroom.

6. Conclusion

This paper presents the playful learning observation tool PLOT, aiming at facilitating qualitative data gathering in classroom situations. It was developed through a literature review of classroom observation best practices, GBL evaluation criteria and cognitive psychology theories of motivation. Particular attention was given to making the tool appropriate for various types of playful learning activity and accessible even to non-gaming observers.

Coding was made by learning session, by type of observation (who, what, why and how) and by motivational construct. This choice allowed for a descriptive and evaluative approach. We tested the table in two different classes with two different games and the results were consistent with the type of game and implementation.

More testing will obviously be required to consolidate the validity of the model, table, and scale but we hope that this tool will provide some opportunities for better use of classroom observation, or inspiration to develop such tools in the future.

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Seven Spells and Peer Tutoring: a Collaborative Mathematics Game Experience

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Abstract: Mathematics anxiety (MA) is a negative emotional response to the manipulation of numbers and the solving of mathematical problems, potentially hindering learning and leading to poor maths skills. Digital game-based learning, in which games are used for education, has been recognised as a potential tool for reducing MA and positively influencing learning, information assimilation, and retention. Peer tutoring is an active learning method that reduces MA in addition to benefiting students academically. This study assessed how 'Seven Spells', a digital maths game developed by our team, affects students' levels of MA and mathematics performance. We hypothesized that this game could be used in classrooms to control MA and potentialise mathematics learning when combined with peer tutoring. 55 children from two 4th classes in an Irish primary school participated in this study. Over a period of three weeks (two days/week), the groups played the 'Seven Spells' game with and without peer tutoring. A mathematics knowledge test, including content covered by the game, was administered at the beginning and end of the study to assess the children's mathematics skills. Game scores were also analysed. At the end of the study, the children participated in an interview, answering questions about the game and the peer tutoring experience. The average game scores increased significantly for the entirety of the children, and also for both groups separately. MA only decreased significantly in the no-peer tutoring group, suggesting that the peer tutoring approach, which was expected to reduce MA, was not successful. No statistically significant differences were found between the peer tutoring and the no-peer tutoring groups in terms of game scores, mathematics errors and MA, further pointing out that the peer tutoring approach was not successful either in reducing MA or in stimulating mathematics learning.

Keywords: digital game-based learning, mathematics, primary school, peer tutoring, mathematics anxiety

1. Introduction:

Mathematics anxiety (MA) is a negative emotional response in relation to mathematics (Buratta *et al.*, 2019; Carey *et al.*, 2017; Krinzinger, Kaufmann and Willmes, 2009) that can hinder mathematics learning and lead to poor mathematics skills, even affecting an individual's future career choice (Carey *et al.*, 2017; Wu *et al.*, 2012). The largest dataset on MA was made available by the Programme for International Student Assessment (PISA) in 2012 (Organisation for Economic Co-Operation and Development, 2013), comprising data from 34 countries: 59% of surveyed 15-to-16-year-old students reported often feeling worried about mathematics classes being difficult; 33% reported feeling very tense with mathematics homework; 31% declared getting nervous doing mathematics problems; 30% admitted feeling helpless when doing a mathematics problem, and an even bigger proportion – 61% - that they are worried about getting low grades in mathematics (Luttenberger, Wimmer and Paechter, 2018; Organisation for Economic Co-operation and Development, 2013).

To properly deal with MA, early identification and handling are crucial (Wu *et al.*, 2012). Digital game-based learning (DGBL), in which games are used for education, has been recognised as one potential tool for both reducing MA and influencing characteristics of the cognitive domain that may optimize learning, such as concentration, information assimilation, motor coordination and retention (Moyer-Packenham *et al.*, 2019; Rocha, Dondio and Tangney, 2016; Vanbecelaere *et al.*, 2019). DGBL can potentially contribute to creating an active, problem-based learning environment (Vanbecelaere *et al.*, 2019). Evidence indicates that the use of game interventions can facilitate knowledge transfer from the virtual to the real environment and elicit greater positive effects on mathematics learning and anxiety through learning activities as they are regarded as more enjoyable than traditional paper-based methods (Castellar *et al.*, 2015; Vanbecelaere *et al.*, 2019). DGBL has been linked to different educational theories, including behaviourism, cognitivism, humanism and constructivism; for this research, the latter view has been considered, with DGBL being used as an active and social process (Sanchez, 2019; Wu *et al.*, 2012). Based on Constructivism (Clarkson and Luca, 2002), peer Tutoring is another active learning methodology which benefits students in social and academic settings and has also been shown to reduce MA in middle school students (Moliner and Alegre, 2020).

The authors hypothesize that the usage of a mathematics game could potentialise mathematics learning and control MA, especially when combined with peer tutoring. Hence, this research aims to answer the following question: Does the use of a digital mathematics game (namely the digital cards game 'Seven Spells', previously developed by our team) combined with peer tutoring enhance mathematics learning and control MA in primary school children?

2. Methods

2.1 Research design

A number of Irish primary schools were invited to participate in the 'Happy Maths' programme, which uses the digital game 'Seven Spells' to support mathematics learning. These schools were contacted via email in which the procedure was detailed i.e. what would be tested, how the researchers would conduct the study and interact with the children and the experiment's duration. Of the schools that accepted the invitation, one was recruited to be part of this specific experiment. Each participant class (two classes, comprising 55 students in total) was visited six times, twice per week during school hours, with the visits being one hour in duration. The study's experimental design is shown in Table 1, which also details the procedures performed during each visit.

Table 1: Experimental design.

6 weeks						
Weeks	**Week 1**		**Week 2**		**Week 3**	
Days	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
Activities	- Game tutorial - modified Abbreviated Math Anxiety Scale - Mathematics questionnaire - Game session	- Game review - Game session	- Game review - Play with or without peer tutoring	- Game review - Play with or without peer tutoring	- Game review - Solo game session	- modified Abbreviated Math Anxiety Scale - Mathematics knowledge questionnaire - Interviews

Letters of consent were sent to the children's parents/guardians asking whether or not they permitted their child to participate in the experiment. These letters were distributed before the start of the study, so that both children and their parents had time to consider and agree/disagree to participate. Children were excluded from the study if their parents did not sign the informed consent or if they did not complete the questionnaires. Of the two participating classes (55 students), one class was randomly assigned to play the game with peer tutoring (27 students) and the other without peer tutoring (28 students).

The first visit consisted of a pre-test phase, in which the children completed two questionnaires. The first questionnaire was the modified Abbreviated Mathematics Anxiety Scale (mAMAS) (Carey *et al.*, 2017), a validated questionnaire that measures levels of MA in students from primary schools. The second questionnaire consisted of a list of mathematics questions related to the content covered by the 'Seven Spells' game and the Irish Mathematics curriculum. The goal of this questionnaire was to measure the children's performance on topics they should know according to their grade (4^{th} class for this experiment). After completing both questionnaires, the two groups were then introduced to the educational mathematics game 'Seven Spells' which covers more than 50 learning outcomes from the Irish Mathematics curriculum. The aim of this online card game is to capture number cards using mathematics abilities. Tablet computers were taken to the schools according to the number of participating children. All children received training in the form of an in-person tutorial given by one of the researchers, who explained the game's mechanics and advised the children throughout their gameplay. Note: children's game scores were collected from this first game session with the 'Seven Spells' game until the last game session on day 6 of week 3.

During the second visit, the game's rules were reviewed during a guided gameplay session with one of the researchers, after which the children played the game again. The third and fourth visits consisted of letting the children play the game, much like in the previous two visits; however, one of the groups did so in conjunction with peer tutoring, and the other one, without. For this experiment, a fixed, same-grade peer tutoring approach was used, meaning that the children maintained their roles throughout the entire intervention and were from the same grade. The tutors and tutees were chosen according to their average scores in 'Seven Spells' during the first two visits, in line with the work of (Alegre *et al.*, 2020; Campbell, 2019). Essentially, a list of the children's usernames was organized according to their scores, from highest to lowest. This list was then divided into two sections; the children who were part of the first section (which included the highest scores) were selected as

tutors, whilst the children in the second section (which included the lowest scores) were appointed as tutees. Tutors and tutees were then paired according to their position in the associated sections i.e. the child at the top of the first section was paired with the child at the top of the second section, and so on.

During the fifth visit, children from both groups took part in a last solo playing session, meaning that the tutors and tutees were separated. In the sixth and final visit, the children once again completed the mAMAS and the mathematics knowledge questionnaires. They were also invited to attend a short interview session concerning the game and the peer tutoring experience.

2.2 Participants

The participants in this study comprised two 4th class groups from a primary school based in Kildare, Ireland. The data included a sample of 55 4th class students. The source data collected during the six days of game play was extracted, cleaned and merged into a single large, anonymised dataset. Data cleaning was necessary due to children missing class or simply not answering questions on the questionnaire. Data cleaning was executed for each variable; game scores, mathematics knowledge and MA. This resulted in different sample sizes for different variables (Table 2).

Table 2: Number of participants and students included in the analyses of each variable.

Variable	Control group No Peer Tutoring	Peer Tutoring	Total
Game Scores	25	20	45
Mathematics knowledge	26	22	48
MA	28	22	50

2.3 Data collection

All results were collected and inputted into a database for analysis. Data was compared considering the initial level of mathematics knowledge and MA and the different groups (the control i.e. non-peer tutoring) group and the peer tutoring group). The project's dataset was analysed to investigate possible correlations and causality between the game intervention, peer tutoring, game scores, mathematics knowledge and MA indicators, identifying whether the peer tutoring interventions had a statistically significant effect on the participating children.

Data from this project cannot be made publicly available because it consists of information about MA and the mathematics knowledge of minors. Thus, data was password-protected with only participant researchers having access to it. Additionally, the children's participation was anonymised: researchers only had access to their usernames, which were assigned as an ID to give access to the game, answer the pre- and post-questionnaires, and be assigned their game scores. The teachers were responsible for completing a spreadsheet which linked the children's usernames to their data and questionnaire results. All data was extracted and analysed using only the game usernames.

2.3.1 Game scores

Game scores were collected from each child and inputted into the 'Seven Spells' database during the game sessions. For this variable, both the highest and the average scores achieved by each child were considered.

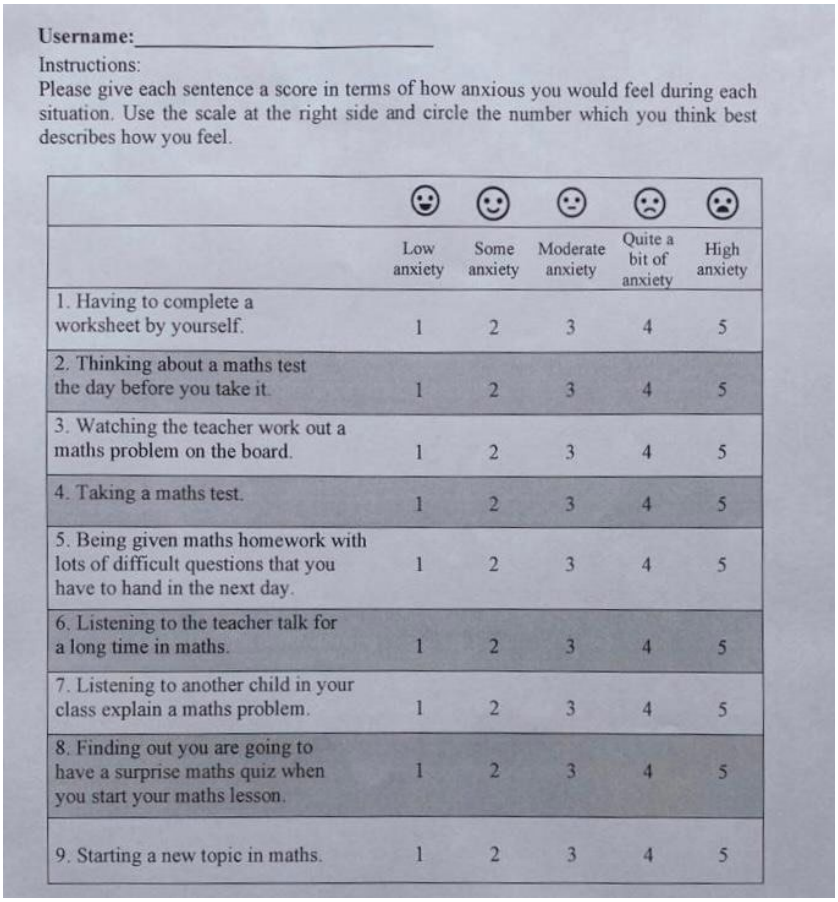
2.3.2 Mathematics knowledge

For mathematics knowledge, a short list of mathematics questions – including content covered both by the 'Seven Spells' game and the Irish Mathematics curriculum according to their grade – was given to each child to complete. The children had ten minutes to finish the questionnaire. For the data analysis, the number of mathematics errors was captured: lower numbers meant that the children committed fewer mistakes, while higher numbers meant a greater number of mistakes.

2.3.3 Mathematics Anxiety (MA)

The modified Abbreviated Mathematics Anxiety Scale (mAMAS) (Carey *et al.*, 2017) was used to measure the children's MA. In this questionnaire, children answered nine questions about MA using a 5-point Likert scale to indicate their feelings during each situation i.e. they circled the number that best described their feelings (Figure 1). Each number is paired with a brief description of how anxious they felt in each situation (1: "Low anxiety"; 2: "Some anxiety"; 3: "Moderate anxiety"; 4: Quite a bit of anxiety"; 5: High anxiety"), along with a simple emoji to

better illustrate that feeling. The minimum possible score for the questionnaire is nine, which would indicate low MA. The maximum possible score of 45 points, would indicate high levels of MA.



Username:_____

Instructions:

Please give each sentence a score in terms of how anxious you would feel during each situation. Use the scale at the right side and circle the number which you think best describes how you feel.

	Low anxiety	Some anxiety	Moderate anxiety	Quite a bit of anxiety	High anxiety
1. Having to complete a worksheet by yourself.	1	2	3	4	5
2. Thinking about a maths test the day before you take it.	1	2	3	4	5
3. Watching the teacher work out a maths problem on the board.	1	2	3	4	5
4. Taking a maths test.	1	2	3	4	5
5. Being given maths homework with lots of difficult questions that you have to hand in the next day.	1	2	3	4	5
6. Listening to the teacher talk for a long time in maths.	1	2	3	4	5
7. Listening to another child in your class explain a maths problem.	1	2	3	4	5
8. Finding out you are going to have a surprise maths quiz when you start your maths lesson.	1	2	3	4	5
9. Starting a new topic in maths.	1	2	3	4	5

Figure 1: The modified Abbreviated Mathematics Anxiety Scale (mAMAS).

2.3.4 Interviews

The children were recruited to participate in interviews on the last day of the experiment, where they were asked a set of open-ended questions about the game intervention and the peer tutoring experience. For the purpose of this experiment, a qualitative analysis was conducted with the answers given to questions in relation to the effect of using 'Seven Spells' in the classroom and the peer tutoring approach.

The following questions were asked:

- Did you learn anything new while playing 'Seven Spells'?
- How did you feel when playing with someone else? Did you prefer playing in a pair or alone? Why?
- Was it clear that in your pair, one was a tutor and the other was a tutee? Or did you feel like there were no specific roles and both helped one another?

2.4 Data analysis

Data analysis was carried out through statistics techniques using IBM SPSS Statistics version 28. Descriptive and inferential statistical tests were realized to draw possible conclusions concerning the advantages of 'Seven Spells' and the peer tutoring interventions, and their effects on mathematics knowledge and MA.

2.5 Ethics

All experiments conducted in this study were submitted to the Technological University Dublin Ethics Committee, and all researchers involved in this project applied to be vetted by the National Vetting Bureau, required for those who will carry out relevant work with children. Applicants received a background check, examining if there was any criminal record or specified information about them. All our approaches to user data comply with the General Data Protection Regulation (GDPR).

2.6 The 'Seven Spells' game

The game used in this experiment is entitled 'Seven Spells', a digital card game previously developed by our team, where players capture cards presented on a digital board. To do so, they match numbers using mathematics' abilities. 'Seven Spells' covers more than 50 learning outcomes from the Irish Mathematics curriculum, including arithmetic operations – addition, subtraction, division and multiplication – and numeric tables.

Examples of gameplay can be seen in Figures 2 and 3, which demonstrate the digital board, the red cards that must be captured by the player and the players' cards, which can be blue – the numbers themselves, used by players to capture red cards – or yellow – the so-called "spell cards", used to capture cards from the board or to modify both blue and red cards, allowing the player to capture them. Both images also show "special" blue cards, the "total" – a card that can capture more than one red card, as long as the numbers on said cards sum up to the number shown on the blue "total" card – and the "max" – which can be used to capture not only cards that are equal, but also less than that number. On the left, the player can also see their username, profile picture, score, number of moves and position in the overall leader board.

Specifically, Figure 3 shows examples of moves, and that more than one move can be made in the same turn, and that each move is highlighted by yellow arrows pointing from the player's card towards the red card(s) on the board. The order of the moves is also shown on the cards' upper left. When a player has done all the moves they want, they should press the "GO!" button to finish their turn. There is also an "Undo" button, where the player can restart their turn. If the player wants to end their match prematurely, they can press the "End" button. Figure 3 also shows the "Master", a fictional character who explains what each card does when a player presses it.

The player has only 40 cards on their deck and should aim to capture the most opponent cards to reach higher scores. Each card the player uses is part of their deck. When there are no more cards on the deck and no more moves a player can do with the cards that are on the board, the match is over. Throughout the match, the player is able to get more cards in two ways: performing a "mega move" – which is any move worth more than 30 points – or reaching a points milestone (every 100 points). When these events happen, the player is able to pick one of 4 possible cards, while still being able to see the boards, which allows for an informed decision about the best card for the situation. An example of a "mega move" and the subsequent card choice can be seen in Figure 4. Players can also change their cards by pressing the "Change card" button, as shown in Figure 5; they can then click one of the cards on the green area, which will be discarded and replaced with one of the cards in the player's deck; the player can also press "don't change" to give up on the idea.

Apart from the in-person game tutorial delivered by the researchers, students would also see a short refresher of the rules at the beginning of every match, as shown in Figure 6.



Figure 2: "Seven Spells" gameplay.

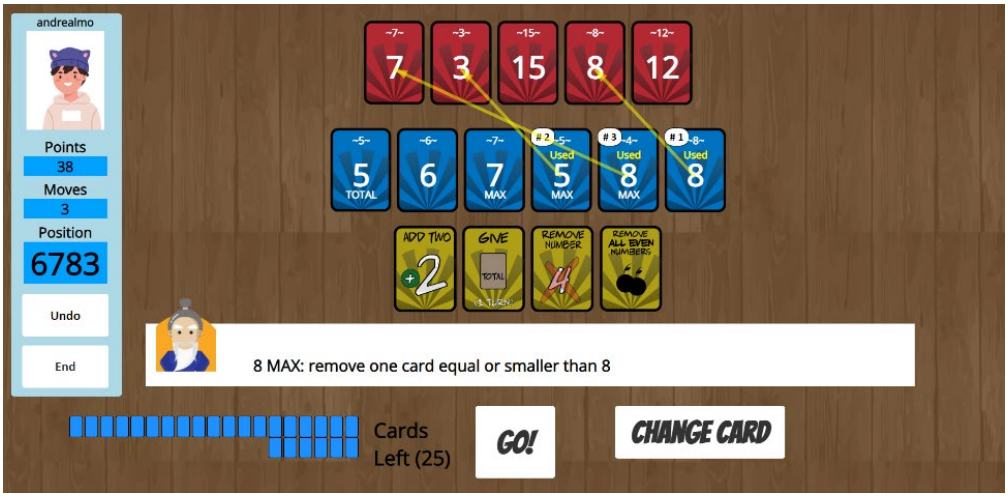


Figure 3: "Seven Spells" gameplay showing the players' moves.



Figure 4: A "mega move" in "Seven Spells", leading to an extra card choice.

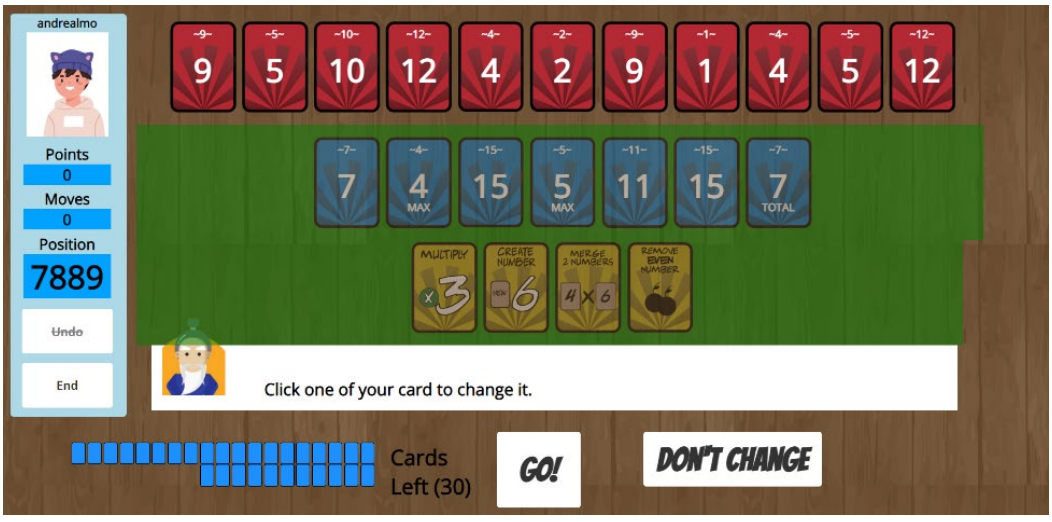


Figure 5: The "change card" button, allowing the player to replace one of the cards in the green area with one of the cards on the deck.

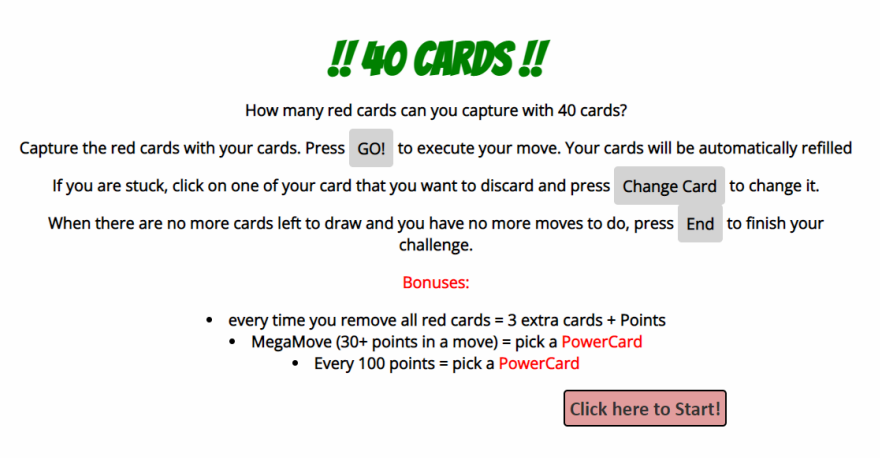


Figure 6: A refresher of "Seven Spells" rules, as seen by students at the beginning of every match.

3. Results

Descriptive statistics for game scores (highest and average), mathematics errors and MA, both before (pre) and after (post) the peer tutoring intervention for the two groups, is shown in Table 3. This includes both measures of central tendency – the average – and measures of variability (minimum, maximum and standard deviation).

Table 3: Descriptive statistics of game scores (highest and average), mathematics errors and mathematics anxiety.

Variable	Minimum			Maximum			Average			Standard deviation		
	No Peer Tutoring	Peer Tutoring	Total	No Peer Tutoring	Peer Tutoring	Total	No Peer Tutoring	Peer Tutoring	Total	No Peer Tutoring	Peer Tutoring	Total
Highest game score (pre)	116	131	116	736	1072	1072	366,4	294,6	332,6	215,0	148,8	201,6
Highest game score (post)	72	92	72	1380	820	1380	369,2	313,2	342,9	285,8	142,8	254,3
Average game score (pre)	36	76	36	391	783	783	178,4	180,8	179,5	151,8	58,4	134,1
Average game score (post)	71	85	71	822	633	822	300,2	259,5	281,1	179,7	109,6	164,0
Mathematics errors (pre)	0	0	0	16	12	16	3,8	3,0	3,4	4,4	1,9	3,9
Mathematics errors (post)	0	0	0	17	12	17	2,7	2,6	2,6	3,9	2,4	3,5
Mathematics anxiety (pre)	9	11	9	40	33	40	21,5	18,8	20,3	8,5	8,1	8,3
Mathematics anxiety (post)	9	9	9	29	34	34	17,2	16,3	16,8	6,9	7,4	7,0

Data on game scores, mathematics errors and MA were tested for normality using the Shapiro-Wilk test. Since data was not normally distributed, as shown in Table 4, all subsequent statistical tests were non-parametric.

Table 4: Normality test for game scores, mathematics errors and MA.

	Shapiro-Wilk		
Variable	**W**	**df**	**p**
Highest game score (pre)	.852	43	<.001
Highest game score (post)	.780	43	<.001
Average game score (pre)	.731	43	<.001
Average game score (post)	.887	43	<.001
Mathematics errors (pre)	.671	43	<.001
Mathematics errors (post)	.730	43	<.001
Mathematics anxiety (pre)	.924	43	.007
Mathematics anxiety (post)	.892	43	<.001

The Wilcoxon signed-rank test was performed for both groups, to compare game scores (highest and average), mathematics errors and MA before and after the peer tutoring intervention. Table 5 shows these results; differences in the average game scores were the only variable with significant change for all the children.

Table 5: Wilcoxon signed-rank test for all children.

	Wilcoxon signed-rank	
Variable	**W**	**p**
Highest game scores	1149	0.49
Average game scores	1797	<0.05
Mathematics errors	1080	0.14
Mathematics anxiety	954	0.02

The Wilcoxon signed-rank test was also realized separately for the two groups in terms of game scores (highest and average), mathematics errors and MA, before and after the peer tutoring intervention to check for the possible effects of the intervention. As shown in Table 6, only the average game scores showed significant increase for both groups. However, MA only decreased significantly for the no-peer tutoring group.

Table 6: Wilcoxon signed-rank test for the two groups separately.

	Wilcoxon signed-rank			
	No peer tutoring		Peer tutoring	
Variable	**W**	**p**	**W**	**p**
Highest game scores	265	0.13	290	0.77
Average game scores	511	0.004	388	0.02
Mathematics errors	275	0.12	261	0.59
Mathematics anxiety	241	0.03	224	0.19

Finally, the difference for each variable – game scores (highest and average), mathematics errors and MA was calculated for each of the children. The Wilcoxon signed-rank test was then used to compare the differences found for the variables in the control group (i.e. non-peer tutoring) versus the peer tutoring group. Table 7 presents the results of such tests. According to the p-values, there was no significant difference between the conditions.

Table 7: Wilcoxon signed-rank test for the differences between variables.

	Wilcoxon signed-rank	
Variable	**W**	**p**
Highest game scores	201	0.26
Average game scores	248	0.98
Mathematics errors	256	0.54
Mathematics anxiety	246	0.41

Additionally, two pairs of children – consisting of two tutees and two tutors – were interviewed at the end of the experiment. The pair of tutees felt they learned something new while they were playing 'Seven Spells' but did not elaborate on how or why. Both described the experience of playing with someone else as something positive, using the words "*fun"* and "*nice"*. They also preferred playing as a pair over playing alone. When asked why they preferred playing as pairs, one of the children stated that they preferred this experience "*because if you get stuck you can see what the other person is doing"*. Both tutees answered that there was no clear role in their pairs; according to one of the interviewed children, "*both helped each other"*.

The pair of tutors recognised they also learned while playing the game. One of them reported: *"Yeah, I think, like, strategies. Just using my brain to think of different things. When I started, I only got like a hundred points. Now it turns out I got a thousand points. When you play a bit more you work your way up. I think I learned some more maths, because I multiply faster. And I don't really add up numbers all the way up to 99. Before I was just clicking on all the cards and just hoped to get the high numbers, but now I count up to these numbers."* The other child stated *"Like, at first I would do two points in a move, but now I can do twelve, twenty four."* When asked what they liked about the peer tutoring experience, Tutor 1 answered that; "*It's exciting*". Tutor 2 continued: "*It's fine. I like it because I noticed that when you are playing, like, you think of only one way but then you see, like, when you chat with somebody else they give you another idea, and then you combine your ideas and then you find an even more powerful way to do it.*" Both tutors, however, preferred playing alone. One of the students said "*I just kind of prefer the independence to do things by yourself... like, you might get into an argument*". Tutor 2 complemented the experience saying that : "*Sometimes you want to do that, like, I want to do that move. And I want to do this other move…*". Tutor 1 continued with: "*But you both are using the same card, so if one uses that card, you can't use the same one."*

4. Discussion

4.1 Game scores, Mathematics Errors and MA

The increase in average game scores was the only significant difference found among all children between the pre- and post-conditions. Independent of the intervention being made with or without peer tutoring, this result was to be expected as the children played the 'Seven Spells' game throughout all six sessions of the experiment, thus becoming familiar with the game's rules and strategies. This was further proved to be true when the increase in average game scores was again significant, but for both groups separately. MA, however, only showed a significant decrease for the no-peer tutoring group. Literature points out that peer tutoring interventions reduce MA (Moliner and Alegre, 2020); thus, this result may indicate that the peer tutoring approach used in this experiment was not successful.

No significant differences were found for any of the measured variables – game scores (highest and average), mathematics errors and MA – between the peer tutoring and the no-peer tutoring group, also suggesting that the peer tutoring intervention had no success in reducing children's MA and stimulating mathematics academic achievement. Another expectation – that players with the higher scores would teach the game's rules and strategies to lower-achieving players – was not met.

Even though there was no statistical significance, there was a decrease in the average of mathematics errors in the mathematics questionnaires applied in the first and last days of experiments. This points towards the game's potential as a mathematics teaching tool; more studies are necessary to confirm this tendency.

4.2 Interviews

The interviews showed that the children positively evaluated the game for their learning. Both tutors and tutees considered the peer tutoring experience to be positive and fun; the tutors, however, elaborated more on their responses. Both tutors, for instance, focused their comments about the learning provided by the game on its strategies and scores, reflecting the quantitative observation that the increase in the average scores was the most significant result. Although the two interviewed tutors viewed the peer tutoring approach positively, they also showed a preference for playing alone. Another important result is that the tutees pointed that there were no clear roles for tutors and tutees in their pairs: this absence of a clear demarcation of roles may have contributed to the lack of success of the peer tutoring approach in terms of learning.

4.3 Limitations

This study has several limitations. Due to lack of time and available classes, the experiment only involved two fourth class classes, both playing the 'Seven Spells' game, one with peer tutoring and another without. This prevented a comparison with other control groups; groups which would receive no intervention, groups who would receive a non-game audio-visual educational mathematics intervention, or traditional, paper-based peer tutoring sessions. The lack of a bigger sample has impacted on data distribution and the significance and generalisability of the results. Furthermore, due to time constraints, the team was limited in the number of interviews which were conducted. Through holding more interviews, it would be interesting to perform a thematic analysis, investigating possible patterns in the children's responses to DGBL and the peer tutoring approaches, and how their opinions relate to their own MA, mathematics errors and game score results.

4.4 Conclusion and Future Research

Mathematics is critical to employment in the science, technology and engineering sectors (Watkins & Mazur, 2013). Studies show that the earlier a child develops a more formal understanding of mathematics related concepts, the easier it is for them to build on these concepts in subsequent mathematical education and perform better (NAEYC, 2020). However, Maths Anxiety (MA) negatively impacts the manipulation of numbers and the solving of mathematical problems, potentially hindering learning and leading to poor maths skills.

One intervention to addressing MA is digital game-based learning. The effectiveness of games as a learning support is well established in mathematics education (Cohrssen & Niklas, 2019; Es-Sajjade & Paas, 2020). In this study, we assessed the effects of applying a digital mathematics game in conjunction with peer tutoring, which is an active learning strategy, like DGBL. The results showed that the average game scores increased significantly for all children and groups, as expected, since students played the game throughout six 1-hour sessions. However, MA only decreased significantly in the no-peer tutoring group. No statistically significant differences were found between the peer tutoring and the no-peer tutoring groups in terms of game scores, mathematics

errors and MA; in this experiment, peer tutoring was not successful in reducing MA or stimulating mathematics learning. Further research needs to be done on the effects of peer tutoring used in conjunction with an educational game intervention for MA and mathematics learning. Studies need to include other control groups and bigger samples.

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Playing With Play Moods in Movement-based Design

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Abstract: New design approaches focus on the lived body's capacity for sensing, feeling, and creating (Loke & Robertson, 2011) are emerging in sport, health, game, play, and innovation. These approaches' engagement in physical movement and movement-based learning becomes focal for designing new practices, artifacts, and interaction designs for movement and movement-based learning games. In movement-based design, a playful mindset is a medium for creating movement, which unifies with the understanding of playfulness as a facilitator of creativity (Bateson & Martin 2013). Aspects of play are also recognised to lower performance anxiety, spurring creativity and conceptualising ideas (Segura et al., 2016). The paper takes a starting point in the triad of play (Skovbjerg, 2013) to state that play is more than an instrument for stimulating design insights but a meaningful practice of moods. Operationalising the triad of play, this paper aims to analyse how different play practices and play moods unfold in two movement-based design workshops. Further to discuss how this perspective of play practice and mood can provide recommendations for movement-based design. With a constructive research design approach, two movement-based design workshops are our cases of data generation. We generated data using video observation, interviews, and observation notes. We found different play media, practices, and moods by an analysis of the participants' actions and interactions. The analysis points out that the participant engages physical and playful in the play moods euphoria and devotion conducive to generation, exploration, and meaningfulness. The paper recommends taking the perspective of play moods as an intrinsic motivating value in play to engage the participant in a playful mood conducive to spontaneity, exploration, and generation. The paper also encourages designers to reflect on the play concepts of ludic (Rule-based activities) and paideia (spontaneously and free activities) when designing through movement-based design.

Keywords: Play Moods, Co-Design, Movement-based Design, Design Methods, Game Design, Embodied Interaction.

1. Introduction

New design approaches focus on the lived body's capacity for sensing, feeling, and creating (Loke & Robertson, 2011) is emerging in the domain of sport, health, game, play and innovation. These approaches become focal for designing new practices, artifacts, and interaction designs for movement and movement-based learning games. Svanæs & Barkhuus (2020) present different types of design approaches working with a body-centred design like soma-based design, movement-based design, embodied design, and designing with and for the body. Movement-based design is defined as design activities, where physical movement is conceptualized as a design material for generating insights (Loke & Robertson 2013), stating that movement is a medium that stimulates, forms and catalyses insights within a design process (Andersen et al, 2020). However, designing for engaging bodily experiences is challenging and bodily design activities are focusing primarily on a technology sustained approach (Segura et al, 2016).

In movement-based design, a playful mindset is a medium for creating movement, which unifies with the understanding of playfulness as a facilitator of creativity (Bateson & Martin 2013). The French philosopher Roger Caillois used the concepts of ludic and paideia to describe the continuum of play; from spontaneously and free activities called Paideia to rule-based activities of Ludic (Caillois, 1961). A Paideia approach is an open-ended and spontaneous process (Bekker, Schouten & De Valk, 2020), whereas the approach of Ludic, on the other hand, is more game-based, rule-based, and controlled activities. The Gamestorming Design Approach by Gray, Brown & Macanufo (2010) has a ludic approach to design, by using design activities as games. Different aspects of play are exploited in movement-based design, where playful ways of expression and acting are characteristics of design activities (Andersen et al, 2020). Activities like object theatre, embodied storming, and roleplaying give designers access to test proposed solutions by acting, explore, and enact alternative futures (Schleicher, Jones & Kachur, 2010). In the methods of embodied sketching (Segura et al, 2016) play and playfulness are a medium for catalysing a creative mindset, an instrument for eliciting creative physical engagement and a way to lower performance anxiety.

These approaches mostly focus on play as an instrument for the design process, as we advocate for understanding a creative movement-based design process as a practice of play. Helle Skovbjerg (2013) definition of play as a triad of media, practices, and moods, allows not only for observing play as it unfolds but to

understand play as a meaningful practice with different ways of being in the play, characterized as play moods. Along with Skovbjerg (2013), we state that play is more than an instrument for stimulating physical creative design insights, but a way of being, that contain intrinsic value and meaning. Operationalising Skovbjergs triad of play, we analyse the generative part of a movement-based design process as a playful practice of moods. Hereby recognising play and movement as the meaning producer and key driver of the design process. This innovative approach has interesting perspectives on how we design with movement and play in the domain of health, sport, play, and play and game-based learning. The aim of the paper is to analyse how different play practices and play moods unfold in two movement-based design workshops and discuss how this perspective can provide recommendations for movement-based design.

This is done through 1) a theoretical description of Skovbjergs triad of play, 2) a summary of two movement-based design workshops, 3) an analysis of how play-practice and -moods unfold and 4) a discussion of the perspective of play practices of moods in relation to movement-based design. The article is relevant for researchers, designers, or practitioners in the domain of play-, game-, health-, and movement-design.

2. The triad of play – media, practice, and mood

In her research on play, Skovbjerg follows Danish and British children for months to investigate how play practices unfold in different settings. She plays with the children and hereby gets a unique first-hand impression of the practices of play and the meaning that is created in this practice. Skovbjerg (2013) defines play as a relation between play media, play practices, and play moods. Where play media (toy) are the objects, children play with, the play practices are the ways of doing with the play media(s), and the play moods are the way of being in these practices – the goal of the play. With this, play becomes a practice of mood, where different ways of doing with play media modulate different ways of being in the play.

Play media is the artifacts being used in play and can both be material and immaterial. The way the play media is used in practice is determined by the situation – e.g., a football will in one situation be a tool for playing football, but in another practice, it can be a bomb that 'kills' if you get hit. The play media offer a space of opportunities – possibly possibilities to be unfolded in multiple ways within the play practice.

2.1.1 From practice to mood

A play practice is the action of a playing activity (Skovbjerg, 2013) and includes ways of doing it. The concept of play practice unfolds in the interplay between repetition and a distance to this repetition. Repeating a practice is not possible, it will always vary, and there will always be a relation between repetition and a distance or change to the repetition. Skovbjerg defines this relationship as the core movement of the play practice, and repetition and distance become a way to create meaning.

Based on the interplay between repetition and distance Skovbjerg determinates two factors that characterizes play practices; 1) if the player in the practice is oriented towards repetition and continuity or towards distance and changes and 2) if the rhythm in the practice is strong and hereby with a long duration, or if it is fleeting. This characterization leads to four distinct play practises: sliding, shifting, displaying, and exceeding.

The last element of Skovbjergs triad is the concept of play moods that unfolds in different play practice. Play moods are a description of the special state of being, which is a precondition for play and a goal when playing. When in play moods people say yes to the most and are open to what can happen. A key point is that rather than being an internal or external state, the mood is a constitutive aspect of our being in the world. A play mood assails us and is happening through our engagement with the doing of play and in our relations towards the people, we are with. The focal point is that the way we are playing (practices) with play media modulates the play moods. Skovbjerg detects the play moods of devotion, intensity, tension, and euphoria.

3. The two workshops

Two movement-based design workshops held at our university are the foundation for the data generation of this research. A workshop is a way to approximate a design practice, and the team-based activities in these workshops are like the teamwork that designers are exposed (Mueller et al. 2014). Tradition in Scandinavian design has taken the form of co-design, where the designers work in collaboration with users and other stakeholders (Sanders & Stappers, 2008). A design workshop with different stakeholders is a way to do or

simulate the participatory co-design work. Table 1 gives a structured overview of the two workshops, the participants, the content, and the design goal.

Table 1: A structured overview of the two workshops

Workshops	*Participants*	*The Context*	*Overarching design goal*
Playground workshop	*16 students, 3 designers from the company, and 2 of the authors*	*The Lab for play and innovation and the Exploratorium.*	*Form insights into the playground company 2022 concept of designing outdoor playful fitness equipment*
Conference workshop	*3 students, 1 programming teacher, 2 engineers and 1 game-based learning designer plus 8 online participants.*	*A Hybrid workshop – Online participants from Europe and participants physically present at the local university*	*Based on a STEAM-X philosophy to create technology-based movement-based learning games.*

3.1 Workshop framing

3.1.1 The workshops content and outcome

As a part of the course of Sports Innovation and Entrepreneurship at our local university in the autumn of 2020, a workshop together with a local playground company was enrolled. 16 students and three designers from the playground company participated divided into groups of 3-4 people. The authors of this paper facilitated the workshops and documented the process. The purpose of the workshop was to ideate perspectives on concepts of designing outdoor playful fitness equipment. The outcome of the workshop was 1) two video sketches of each group illustrating a playful physical activity and 2) a rapid prototype of the equipment that supports the activity.

Both workshops were held inside the Innovation Lab and at an outdoor Athletic Exploratorium, a combination of a track and field stadium, obstacle course, parkour installations, and a cross-fit area, and first lasted 6 hours and the second lasted 3 hours.

As a part of a conference, a movement-based hybrid workshop on designing STEAM-X learning games was held at our university together with online participants from Europe. Three sports sciences students, one programming teacher, three engineers and one person from the game-based learning industry participated physically in the workshop and eight people were participating online via the Zoom platform. The aim was to create movement-play learning games through STEM teaching. The outcome of the workshop was 1) video sketches illustrating a physical learning game and 2) a rapid prototype of the technology supporting the activity.

3.1.2 The structure of the workshops

The two workshops had different constraints and design goals, but they shared the same structure of a movement-based ideation part at the Exploratorium. The workshops can roughly be divided into three parts:

The first part was located inside the Innovation Lab. The local playground company in the first workshop and the teachers of the conference workshop framed the design challenge, the design process, the context, and the design goals. Part two is the movement-based generative activities located at the Exploratorium. We allocated a specific equipment-based space for each group with artifacts such as rope, balls, boxes, wooden poles, plates, tumbling equipment, hurdle, and sledge. Using movement-based instructions and inspirational methods cards the groups created two video sketches of playful physical activity. In the last part, participants analysed the video sketches together and made a quick mock-up of the equipment. At the conference workshop, the participants made a technology mock-up.

3.1.3 A movement-based design approach

The workshops were framed with the goal of using the moving body first approach informed by Segura et al (2016) and Loke & Robertson (2013), who both recognize that movement is a central part of the early stages of a design process. Locating the participants in different limited physical spaces, we supported the participants to use the physical space as a design resource. Participants were divided into small groups to lower performance anxiety and to stimulate social aspects as a design resource for higher engagement, positive emotions, and mutual eye contact (Segura et al, 2016]). By using movement-based inspirational and instructions method cards in the generative part of the workshops, the aim was to give the participants autonomy to facilitate their own process.

4. Research design and methods

Our study is based on a Constructive Design Research (CDR) approach (Koskinen et al, 2011), where knowledge is generated in the construction of movement-based design methods cards and the test of the cards in two workshops. The Movement-based design methods cards used in the workshops are part of an Erasmus+ project developing a movement-based method card toolbox.

4.1 Methods to generate data

To document the two workshops, data from video observations, video sketching and later semi-structured interviews were generated.

GoPro and a video camera were used to video observe the participants' embodied experiences and actions (Alaoui et al, 2015) and hereby capture the ephemeral movement. Generating visual material from 5 groups the aim was to gather data to analyse and reflect the participants' bodily actions.

As a part of the design process, the participants did a video sketch recording their best physical design ideas (Hammersley & Atkinson, 2007). The data of the self-recorded video material was a way to provide participants with a sense of agency and an opportunity to speak for themselves by showing their bodies (Hammersley & Atkinson 2007). Data from the self-recorded videos were used to find key sequences in the video observations.

Semi-structured online interviews (Smith & Sparke, 2016) using Zoom were conducted to understand the participants' experiences and reflection on the generative part of the workshops. Five participants participated in the interview, one from each video observed group. During the interview we showed identified key video sequences, to make it easier for the informants to describe their bodily actions and experiences (Smith & Sparke, 2016).

4.2 Data treatment and analysis

To identify, analyse and find patterns within the generated data the analytic work is informed by the thematic analysis (TA) (Braun, Clarke & Weate, 2016). The analysis is based on the participants' actions and doings primarily based on the video observation. Transcribing the identified key video sequences the transcription is interpreted as relevant material (Heath, Hindmarsh & Luff 2010).

4.2.1 The analytic work

Informed by the flexible approach to the six steps in TA (Braun, Clarke & Weate, 2016), the analytic approach has been reflective and iterative. First step: Becoming familiar with the video material by transcribing and observing the video observations. The second step is to code the transcription. The codes can be characterized as data-driven because the process is guided mostly by the data. Steps 3 to 5 concern the organization of the codes to possible themes, and then revising these themes to form a rich analyse of data, and themes of play practices and play moods emerged. Through a dialectic process including the codes, the video observations, and the theory of Skovbjerg, the themes were qualified and refined. The participants' descriptions of their actions in the process from the interview, were used to ensure the interpreted actions and the generated themes. Step 6 is to write the analysis.

5. Play and (play) moods in a creative movement practice

5.1 Play media is generative

The space of opportunities, that the play media offers the player is by Skovbjerg (2013) described as the concept of affordance. James J. Gibson states that the world unfolds itself in possibilities for action (Skovbjerg, 2013), and affordance is what the environment offers to the individual. The affordance of the play media is a "for this" and only relevant in relation to the play practices and hereby embedded in the meaning structure of the play practice.

At the first stage of the ideation process, the participants were instructed to individually explore different movement possibilities with self-chosen artifacts at the selected location. At the fitness-stand of the Exploratorium Andreas, one of four participants, picks three rings, a rope, and a stick and starts to explore ways to move with these artifacts:

> *Andreas looks around and finds some rope and starts to tie it to a small stick. He looks at the hula hoop, that is placed on the fitness-stand, throws the stick through the hula hoop, and afterwards brings the stick back by pulling the rope. He tosses again and hits through two rings and continues to throw the stick from multiple angles and distances. He laughs before he creates a hoisting system with the rope and the fitness-stand and sits on the stick and swings. He repeats this only a few times before he ties the rope to the stand and starts juggling with a ring on the rope.* (Condensed part of the transcription)

The affordance of the play media is defined when used, Andreas explores how he can play with these play media in different ways. After he had thrown the stick multiple times, he constructs a hoisting system and uses it as a swing. The exploration of the rope unfolds different ways of playing and creating meaning, from mastering a throw, to swinging from side to side. Later, he ties the rope to the fitness stand and juggles with the hula hoops, which illustrates that the affordance of the play media is changed due to the way Andreas plays with them. His bodily experimentation with the play media drives the process.

By actively engaging in the exploration of the affordance of the play media, Andreas is creating three different ways of playing and thereby three design ideas. Andreas's ways of doing with different play media are generative for the design process and the engagement with the play media can here be seen as a creative practice.

5.2 Generating design ideas by adjusting - a mood of devotion

At the conference workshop, one group of three participants started the ideation using the allocated methods cards. The end goal was to video-sketch a learning game. They were instructed to ideate with an artefact exploring the artifacts' different movement possibilities. The group also picked an inspirational card with "Mastery". While Andy holds the camera and talks with the online participants the other start:

> *Mikkel takes a stick and starts juggling, quickly Jonas picks two cones and starts imitating Mikkel's juggling. Shortly after they both fail, and Mikkel says:" Or, we can master something together", turns to Jonas and they start to joggle together with the stick and the cones. Jonas puts in another stick in the play. They are concentrated and try to cope with the motion of each other to time the throw. In the beginning, the rhythm of the toss is slow, but shortly the frequency of the throw arises. "Sticks go high, and cones low"! They smile and laugh when-ever they hesitate to throw. "Let's try to throw the sticks into the cones" – Mikkel says and keeps the cones, while Jonas starts tossing the sticks into the cones. He misses two times, and they change and continue.* (Condensed part of the transcription)

Throughout this practice, Mikkel and Jonas keep the repetition of throwing with the play media, having a strong repetitive rhythm of the play practice. The repetition of throwing is maintained with minor distance and the play evolves through small adjustments. Mikkel and Jonas change the practice from juggling alone to "mastering something together". Soon, Mikkel and Jonas make rules of how and when to throw the sticks and the cones to each other striving to keep the rhythm of the practice, and the small adjustment is oriented to keep the play practice going. This characterizes the play practice of sliding, keeping a strong rhythm aiming for being in the play and Mikkel and Jonas are oriented to sustaining the activity.

The play mood of sliding is characterized as devotion, where players normally play for a long time. This play practice and moods are the archetypes, and in real-life never just one kind of mood. Being in the mood of devotion Mikkel and Jonas are concentrated and focused. Their openness to create new meaning is firstly focused on a wish for being in the play and what is meaningful, made optional through small adjustments.

Through the play practice, Mikkel and Jonas are experiencing and exploring the design idea of juggling together, and by making small adjustments and rule changes, the play practice is meaningful and generative for the design process.

5.3 The mood of euphoric – creating ways of doing

At the playground workshop, five participants are located at a bridge made of rope. The quote is from the beginning of the generative part, where the participants just arrived at the place with the allocated artifacts:

> *The five participants stand in a circle. Jonas picks up a plastic square and starts throwing it around. They start throwing a ring and a bottle of water. The artifacts are in the air, and at one point, Simon managed to catch the bottle in a stretched arm. Everybody laughs and cheers. Then Lasse starts to drag Morten around on a sledge and meanwhile Charles is swinging in the ropes under the bridge. Lasse picks up a ring*

> *and Simon throws the ball over the bridge, and when it falls down Lasse is moving so it falls into the ring. This section is repeated, but this time the ball falls through the ring and back from the ground in between Lasse's legs. This leads to several participants burst out "Uhhh" and start to laugh.* (Condensed part of the transcription)

As a part of the design process, the participant is trying to explore how they can move with different play media at the location. They interact by throwing artifacts at each other's, pulling each other's or by leading each other. When the participants are standing in a circle and throwing the square at each other, Jonas takes the square and sits on it, and Simon brings in a bottle. There seems to be an intention to exceed the practice when Jonas sitting on the square. Using play media towards exceeding a practice is characterized by the mood of euphoria. Euphoria is open-minded because the participants must be constantly open to new ideas and expect silliness. The players' production of meaning is formed by constantly seeking new ways of expression to change the former practice

This production of meaning becomes generative because there are constantly new ways of doing it. The practice can be described as: 'it is not what makes sense to do, but what can I do?'

5.3.1 A change in play mood to sustain a practice

After three minutes the participants find a rhythm in throwing the ball into the bridge, which changes the practice of exceeding. Keeping the same action of throwing the ball over and into the bridge, but with minor changes in catching the ball, the participant focused on sustaining the activity. This is characterized as a sliding practice with a repetitive rhythm to maintain the play practice. Firstly, the person under the bridge stands on a plate, then a rolling stick, then a hurdle becomes the target, and later the ball must be tossed over the bridge to be bounced by two persons with a giant stick into the hurdle. By making small changes in the activity, the focus for the participants is to keep playing. The mood can be characterized as devotion.

6. Discussion

The analysis points towards, that the way the participants move, engage, and interact with play media is generative and can be defined as a play practice of moods. Using play media is not an unfamiliar thing in design and movement-based design e.g., Schleicher, Jones & Kachur (2010) uses acting roles, Segura et al (2016) use the physical space and artifacts as a resource for the design process and Loke and Robertson (2013) use the body as a material within the design process.

The view of design as an interrelationship between artifacts (media) practices (methods) and moods is new and different from other perspectives in movement-based design. By adding a layer of mood, we highlight a focus on letting play moods characterized as open-minded and spontaneous being drive the process. With this play mood philosophy, we advocate for a perspective in which play moods become the driver and value of the process. This aligns with Segura et al (2016) statement, that play may be used as both a method (medium) and as an intrinsically motivated goal. This is illustrated by Andreas' bodily experimentation with the play media, where the practice is changing in relation to his exploration of the affordance of the play media. The playful practice and his physical movement drive the process and as such play turns out to be both the goal and the medium as proposed by Segura.

6.1 Ludic and paideia

The workshops have aspects of both paideia and ludic (Caillios, 1961), with few rules like an advocated location, a fuzzy end-goal, and self-facilitated method cards. More rules e.g., social regulation by turn-taking or spatial-social organization (Segura et al, 2016) of the participants represent a ludic approach to the generative aspects of the movement-based design. The ludic approach is mostly present in design activities when e.g., framing the design processes, creating rules and does and don'ts, but also setting an end goal like e.g., Gray, Brown & Macanufo (2010). In Bekker, Schouten & De Valk, (2020) the focus is on an open-ended playful approach to design, representing a more paideia approach, where spontaneity and improvisation drive the process. This echoes our ambition of letting the spontaneity and openness within the practice of play drive the process.

The reflection of the balance between regulating and controlling (Ludic) or letting the participants be free and spontaneous (Paideia) is an important reflection that the designer must consider being in movement-based design practice. This can be a difficult task as Bekker states:

An important challenge of designing for open-ended play is how to find a balance between, on the one hand, provide some triggers for play and some minimal structure and, on the other hand, not to provide too much structure but leave enough room for improvisation.

7. Conclusion and Recommendations

This paper takes the point of departure in constructive design research and presents how play-practices and play moods hold the potential to vehicle generative processes in movement-based design, based on empirical insights from two workshops. The analysis points toward participants being in the play moods of devotion and euphoric drives their engagement in the physical play practices conducive to generation, exploration, and meaningfulness. The participants innovate, play, and move together to design for play, fun, and movement. Play and movement become both a goal and a means for the design.

The paper recommends designers, researchers, and practitioners to reflect on the relationship between play media, practice and mood when designing in the domain of play, game, health, and movement-based design. Also, we encourage designers to reflect on the continuum of ludic or paideia when designing through movement-based design. We recognize that further research is relevant to investigate how designers can actively work with play moods when designing for play, game and health.

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Comparing the Student Engagement with Two Versions of a Game-based Learning Tool

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Abstract: Research has shown that game-based learning techniques positively impact students' engagement, motivation, and learning outcomes. We performed a study to explore the differences in student engagement with a game-based learning tool implemented on two different platforms: mobile and web-based. We developed two versions of a peer-quizzing game where the students can create quiz questions related to the learning material, which their peers can attempt to answer. The students can create three types of questions: Multiple Choice Questions, True/ False, and short answers. Students from a first-year introductory programming computer class were recruited to evaluate both versions of the game during one academic term (four months) during the Covid-19 pandemic when classes were entirely online. A bonus participation mark of up to five percent of the course was offered to students who posted at least three questions per week. In addition, we collected data about the students' in-game activities for the study duration. The Mann-Whitney U-test results show no significant difference in the engagement between the web and the game's mobile version. However, students posed more questions in the mobile version than in the Web version of the game. On the contrary, students solved more questions in the web version than in the mobile version. We have learned from the study that both game-based learning platforms effectively engage students. We also collected data about the students' experience with the game in a post-study survey. The responses show that both game versions got similar user experience ratings.

Keywords: Game-based Learning, M-learning, Peer-quizzing, Engagement

1. Introduction

The use of technologies in learning and teaching has increased over the last decade and allowed us to explore and improve how we deliver the learning materials. With the availability of various technology platforms, such as web, mobile, virtual, and augmented reality, new ways of presenting learning and evaluation materials are possible (Pedro, Barbosa and Santos, 2018). Gamified and game-based learning tools are used to enhance the learning process further (Grund, 2015). Gamification is the process of using game mechanics and dynamics in non-game contexts (Kapp, 2012). Moreover, game-based solutions pursue a secondary goal of motivating users to engage in target activities (Deterding *et al.*, 2011; Qian and Clark, 2016). Various studies have presented positive results in using both gamified and game-based learning solutions in education (Connolly *et al.*, 2012; Dichev and Dicheva, 2017). Most studies reported that both gamified and game-based learning solutions help motivate and engage the learners and may improve their learning outcomes (Zainuddin *et al.*, 2020).

Mobile learning games are becoming increasingly popular because of how compact and convenient they are. In addition, the sensors generally found in smartphones can be utilized to enhance their apps further. For example, learning apps can use GPS to locate learners and deliver tailored lessons to the context. On the other hand, web-based applications are popular too because of how easy they are to access. The user only needs an up-to-date web browser to use a web application. Web game applications also require fewer computational resources compared to full computer games.

The study reported in this paper explores two versions of a game-based learning tool that encourages the learners to create quiz questions and answers of their own. The learning objectives for both versions of the game are to persuade learners to form high-quality and tricky questions about the learning material, to develop critical thinking skills, and playfully practice for quizzes and exams with their peers. In addition, a question-and-answer bank of student-generated quizzes is built as a by-product, which can be used for class quizzes and exams. Specifically, in this paper, we aim to compare the two versions of the game and find which version is used more actively (i.e., engages the students more) and supports a better learners' experience (using a post-study survey). Our initial findings suggest that the students like both versions of the game; activity-wise, the mobile version had slightly more student-generated quizzes.

2. Background

The recent popularity of game-based learning solutions has influenced researchers to experiment with various approaches (Deterding *et al.*, 2011). Researchers using game-based learning tools have mostly reported positively impacting their implementations (Connolly *et al.*, 2012). Learners like gamified and game-based learning solutions, because of the extra layer of entertainment and excitement added by the mechanics and dynamics of an existing task (Krath, Schürmann and von Korflesch, 2021). Some commonly used game elements in non-game contexts are points, badges, and leader boards. Using these game elements, the hardship of the main task becomes less noticeable because of the rewards and satisfaction playing with the game elements brings. Thus, the learners feel motivated, engaged, and captivated by the system.

The use of game-based learning solutions and the level of engagement varies and depends on the type of platform and the target users (Morschheuser *et al.*, 2017). While game designers try to make their systems as inclusive as possible, the quest for a universal solution is still elusive today. Some designers use artificial intelligence to adapt their systems to match the individual learners' needs (Dalponte Ayastuy, Torres and Fernández, 2021). Mobile phones are among the most popular platforms for both gamified and game-based learning solutions. M-learning has existed for some time (Georgiev, Georgieva and Smrikarov, 2004). Most mobile phones released after 2015 are powerful enough to process rather complex programs. Many mobile applications exist for research that utilizes gamification and games to facilitate behaviour change (Bartel and Hagel, no date; Oyibo *et al.*, 2019; Olagunju, Ogenchuk and Vassileva, 2021).

3. Design and development of the two games

Most students are strongly attached to the Internet and mobile devices because of their popularity and availability (Kirschner and Karpinski, 2010). In addition, online activities increased during the Covid-19 pandemic because most learning institutions closed, and classes were delivered online. Thus, students spent more time on their computers and mobile phones to stay connected with their peers and teachers. To utilize the online learning situation during the pandemic, we have used two versions of the same game-based peer-quizzing application with minor differences in the features: a web and an android mobile application. Details about both versions and their similarities and differences are discussed next.

3.1 An overview of the game

We have developed a peer quizzing game called the Tower of Questions (ToQ) (Kiron *et al.*, 2019). The students play by logging in with their pseudonyms (gamer IDs) and passwords and creating “towers” by posting questions related to the learning material. Other students attack the towers by answering or solving other players' questions. The students can choose from three categories of questions/towers: Multiple Choice Question (MCQ), True/False, and Short Answer (SA). The MCQ and True/False questions are automatically evaluated, whereas the answers to SA need to be reviewed by the creator within one week. If the answer to the question is correct, the tower is “conquered”. All the conquered towers are available for all players to view and study, by inspecting the questions and answers.

There is a points system in the game called the “gem bank”. The gem bank has a finite number of gems from which a small portion is awarded to the player when they create towers. When a player attacks a tower successfully, they get a portion of the gems initially awarded to the tower’s creator. For example, initially, the gem bank had one hundred gems. When a player builds a tower by asking a question, they will receive ten gems from the gem bank. If other player attacks and conquers the tower, they would receive four gems from the ten gems awarded to the creator as a reward for conquering the tower. The player who created the tower will keep the remaining six gems. Because each new tower takes away 10 gems from the bank, the more questions are created, the fewer gems remain in the gem bank. If there are no gems left in the bank, no further questions can be posted, and no new towers can be created. Thus, the number of gems available in the bank controls the number of questions created by the group of players, as desired by the instructor. Screenshots from the web-based and mobile versions of the game are provided side by side in Figures 1-6.

Table 1: Screenshots from both versions of the game

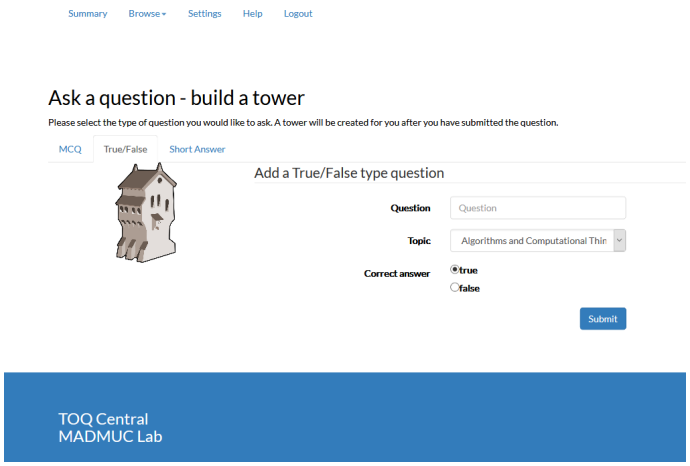


Figure 1: Building a new tower in the web game



Figure 2: Building a new tower in the mobile game

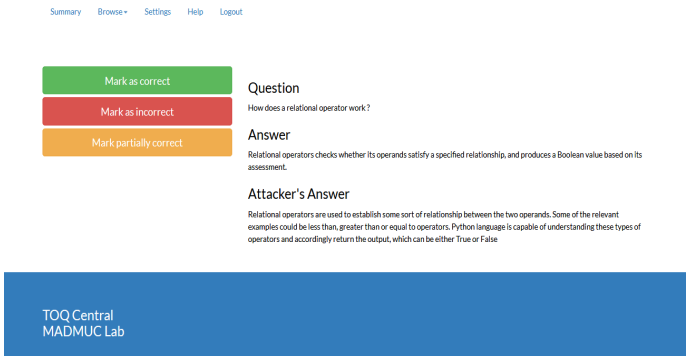


Figure 3: Viewing a short answer from the creator's perspective



Figure 4: Viewing a question and the answer

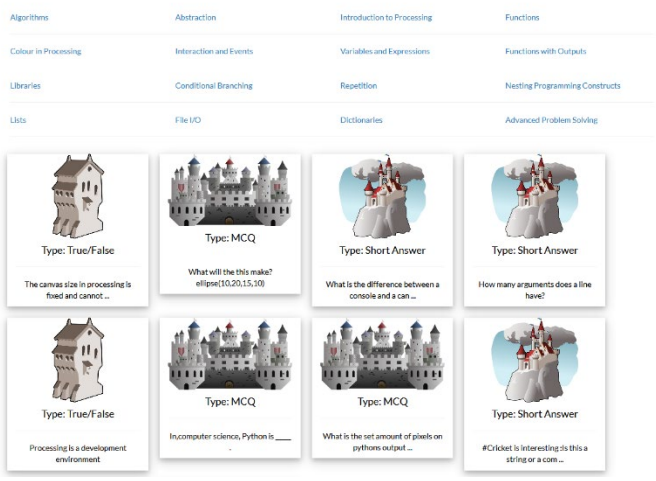


Figure 5: The conquered towers or answered questions in the web game

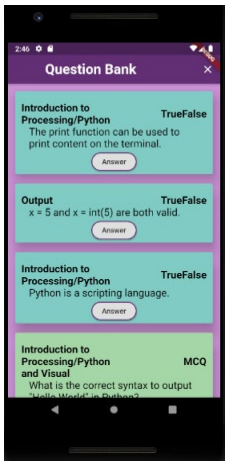


Figure 6: The conquered towers or answered questions in the mobile game

3.2 Similarities and differences

Although both versions of the application share most of the learning and game features, there are some differences. Similarity-wise both versions of the game have a gem bank, but do not have a leader board; both versions limit the number of questions the students can ask, and maintain player anonymity (via aliases) in the game. Regarding the differences, the mobile version does not have a flagging feature. The flagging feature is used in the web version of the game to allow players to report spam, duplicate quizzes, and low-quality or trivial questions. The other differences in the mobile version are in the user interface layout. The aesthetics of the mobile version had to be adjusted to fit the size of the screen. The web version was developed and tested before the mobile version.

4. User Study, data analysis and results

This section presents the design of our study to determine which version of the game is more effective in engaging students during the pandemic and to discuss the result of the data analysis performed. One hundred twenty-one participants from our university's first-year programming language course CMPT 145 were divided into two groups: 75 in group W (used web version) and 46 in group A (used application version). The reason for having few participants in group A is that the application version of the ToQ game is only available on Android devices. Hence, participants with iPhones or other devices had to use the web version of the game.

The study was approved by the Behavioural Research Ethics committee of our University and lasted for an entire academic semester (four months), from January to April 2021. At the beginning of the study, the participants completed a pre-study questionnaire and the end of the semester – a post-study questionnaire. Participants in group W collectively created 1328 towers throughout the semester, while group A created 961 towers.

The independent variable in our study is the game version used by each experimental group. The dependent variables are the engagement metrics: the number of active users per week, the number of towers created each week, and the number of towers successfully attacked by the active users each week. For all results, we considered active users to be anyone who logged in and created at least one tower in the system in a week. The descriptive statistic indicates differences between the application and the web version of the game. Mann Whitney U-test was used to test the statistical significance of the results.

The null and alternative hypotheses for dependent variables are as follows:
H_0: There is no difference between the number of active users (towers created and solved) in groups A and W.
H_1: There is a difference between the number of active users (towers created and solved) in the A and W groups.

The results (the values of the dependent variables) are presented below:

Active users: Figure 7 shows the percentage of active users in a week by the total number of participants in a group. The graph shows the percentage of active users in both game versions each week for 12 weeks of the full term. As more users participated in group W, the graph shows that the number of active users was slightly higher in the W group in 8 out of the 12 weeks. In three of the 12 weeks (excluding the week of Feb 14-20, the spring break), the A group had a higher percentage of active users. The Mann-Whitney U test result shown in Figure 8 indicates that the difference between the two groups is not significant (H_0 confirmed).

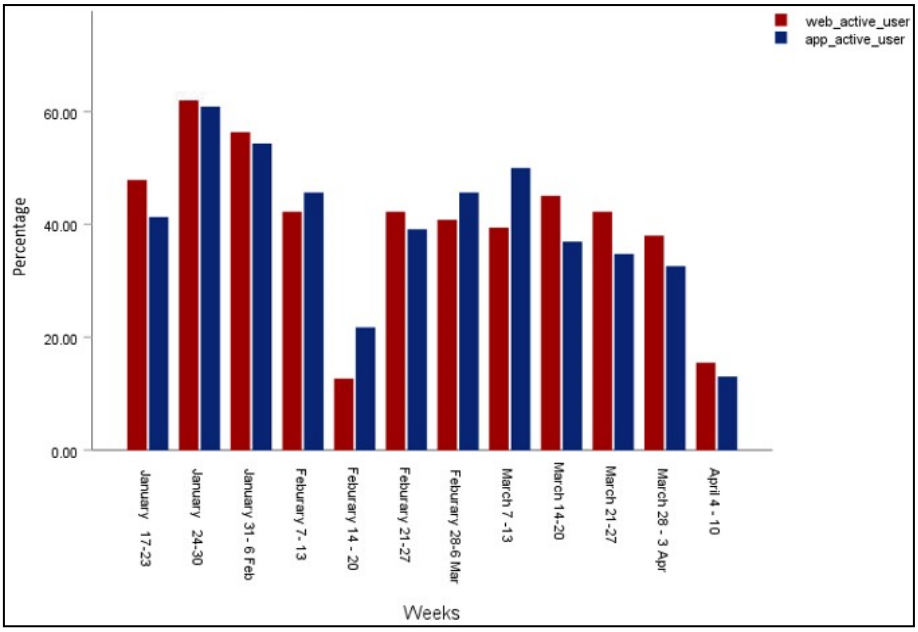


Figure 7: Number of active users per week in each group (App and Web)

Test Summary	
Mann-Whitney U	78.000
Asymptotic Sig.(2-sided test)	.729
Exact Sig.(2-sided test)	.755

Figure 8: Test summary of active users per week in both groups

Towers created: Figure 9 illustrates that the mean number of questions posted (towers created) by the active users each week in the App version is consistently higher than that of the Web version of the game. The Mann-Whitney U test result shown in Figure 10 shows that the difference is significant (H_1 confirmed).

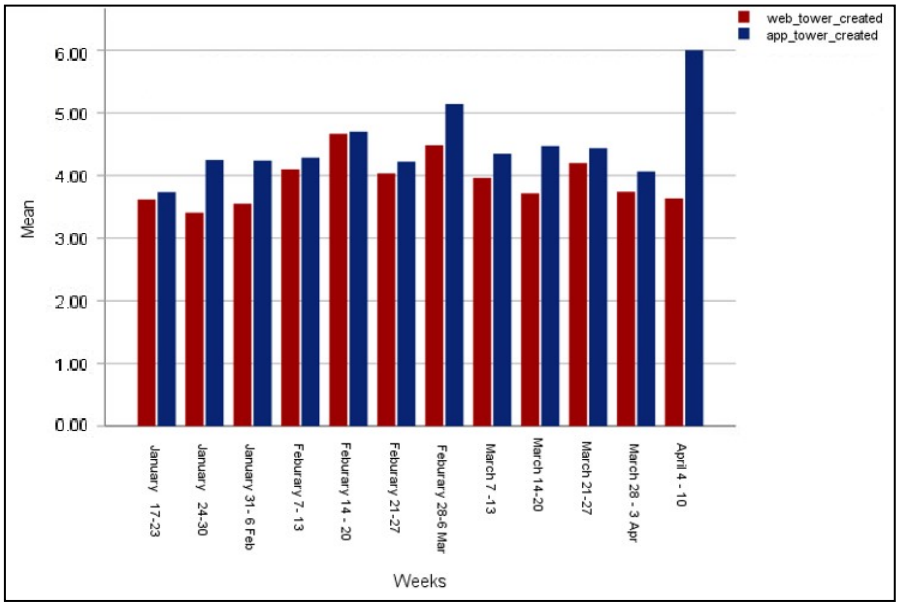


Figure 9: The number of towers created by active users in both versions per week.

Test Summary	
Mann-Whitney U	25.000
Asymptotic Sig.(2-sided test)	.007
Exact Sig.(2-sided test)	.006

Figure 10: Test summary of towers created by active users

Towers Solved: The results for the number of towers (questions) conquered (solved) only include the number of users who successfully attacked the towers, and it does not include the users who tried to answer the question but failed. The graph illustrates that the participants in the A group were enthusiastically solving the question towers before the reading week, but their participation dropped significantly after the reading week. After the spring break (Feb 14-20), the participants in group W became more active in solving questions, and only in two weeks did the participation of group A come close to that of group W. The result of the Mann-Whitey U test shown in Figure 12 confirms that the difference is significant (H_1 confirmed).

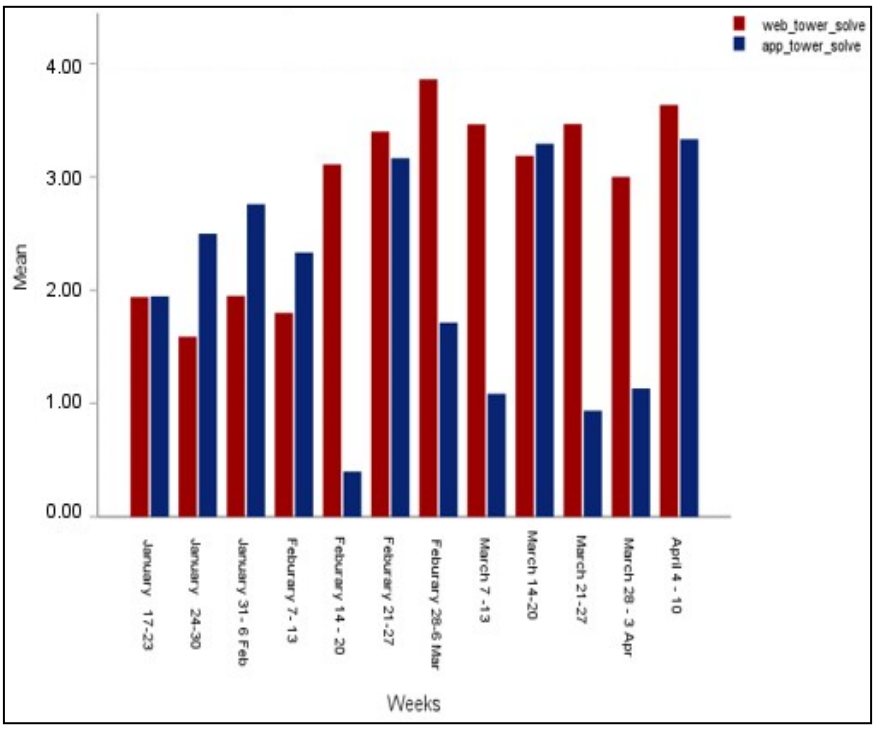


Figure 11: Tower solved by active users in both versions each week.

Test Summary	
Mann-Whitney U	108.000
Asymptotic Sig.(2-sided test)	.038
Exact Sig.(2-sided test)	.039

Figure 12: Test summary of tower solved by active users

User Experience: In the post-survey questionnaire, we asked the participants to rate their game experience with the game on a scale of one to five, with one being the least and five being the highest satisfaction rating on the Likert scale. Forty percent (20 participants) of the 46 students in the A group participated in the post-survey questionnaire. The average satisfaction rating of the App version was 3.65 out of 5. On the other hand, 53% (38 participants) of the group W participants completed the post-survey questionnaire, and their average satisfaction rating was 3.86 out of 5.

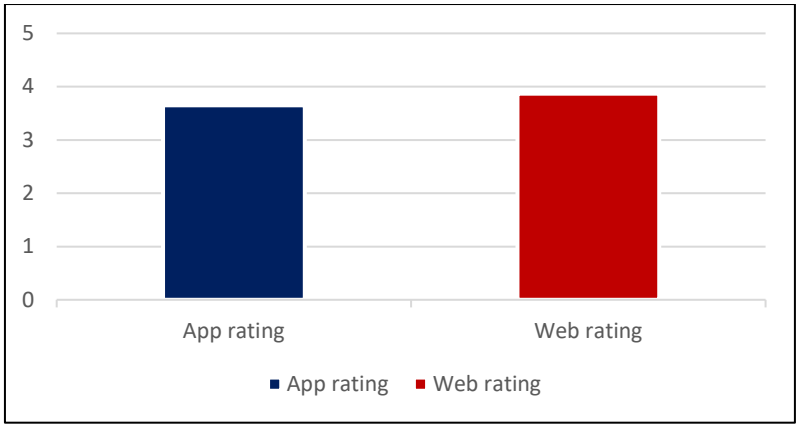


Figure 13: User rating for both versions.

4.1 Results Report

To check the normality of the data, the Shapiro-Wilk test was performed. We have presented the results using two methods in SPSS: the Mann-Whitney U-test and the Independent Sample T-test.

4.1.1 Active Users

The total number of users who actively participated in our study was 117. Of the total users, 60.68% of participants signed up for group W, whereas 40.38% actively participated in the study. For group A, 39.31% (46) students were recruited, and the participants who actively participated were 39.67%. The statistics show nuance in the average active users in both versions. This result is also explained using a Mann-Whitney U test in SPSS. The test evaluates the difference between the engagement of the active users in both groups. Results analysis indicates no significant difference between the active users in both groups. The mean number of active users for group W (M = 40.3) is slightly higher than the mean of the number of active users in group A (M = 39.6), but the Mann-Whitney test indicated that this difference is not statistically significant, U = 78, z = .347, p > 0.05 (Figure 8). The mean difference of active users is by chance because the significance value p is greater than 0.05, thus confirming the null hypothesis H_0.

We also performed an independent sample T-test to test if Group A and W have a statistically significantly different number of active users. Results show that Group A (SD= .78) has more active users statistically than group W (SD = 1.34). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 0.80, p = 0.378. The independent samples T-test was associated with no statistically significant effect, t (22) = 0.832, p = 0.414. Cohen's D was estimated at 0.340, a small effect size based on Cohen's (1992) guidelines. Thus, no difference has been found between the number of active users in Group A and W. The statistical analysis confirms that there is no difference between both groups, so we retain the null hypothesis (H_0).

4.1.2 Towers created

We can show that more towers, on average, were created by an active user in group A of the game. We conducted a Mann-Whitney U test to check the difference between the number of towers created in groups A and W. The mean and median for towers created by active users is higher in group A compared to group W. The test analysis shows a significant difference between the number of towers created by active users in groups A and W. The median of towers created by the active users for group A (MD = 431) is higher than in group W (MD = 385), and the Mann-Whitney test indicated that this difference is statistically significant, U = 25, z = -2.714, p < 0.05 (Figure 10). These results show a substantial difference between the tower created in both groups. Also, the two-tail significance value is less than 0.05, which means we can reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). The report shows that the mean of towers created in the mobile version (M = 449) is higher than the mean of towers created in the web version (M= 392). These results show that the participants preferred to post questions using the application version of the ToQ. The post-study questionnaire contained the question "Which feature(s) did you like in the game?". The data shows that 17 out of 20 participants preferred creating a question in the mobile version. The report shows that participants prefer to use the mobile version while posting a new question.

Moreover, the results of an independent sample T-test show that Group A has higher mean towers created by active users (M = 8.83, SD= 1.47) than group W (M = 5.80, SD = 2.68). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 1.43, p = 0.244. The independent samples T-test was associated with a statistically significant effect, t (22) = 3.42, p = 0.002. Thus, there is a difference between the number of towers created by active users in Group A, and W. Cohen's D was estimated at 1.39, which is a considerable effect size based on Cohen's (1992) guidelines.

4.1.3 Towers solved

We investigated the results for solving towers by active users in both groups each week. Figure 11 shows the active users' mean of successfully solving the question towers. We had not included the data when users tried to solve the question but were unsuccessful. The result shows that, on average, the participants in group W solved 34.48% more questions than group A throughout the term. A Mann-Whitney U test is conducted to determine whether there is a significant difference between the towers solved by active users every week in the A and W groups of the game. Results of that analysis indicated a significant difference between the tower solved by active users of both groups. The number of towers solved by the active user in group W (MD = 314) is higher than the tower solved by active users in group A (MD = 214). The Mann Whitney test indicated that this difference is statistically significant, U = 108, z = 2.078, p < 0.05 (Figure 12). Furthermore, we accept the alternative and reject the null hypothesis because the two-tail significance value is less than 0.05 (Figure 12). The statistical report shows that the mean of the number of towers solved is higher in the web version (M = 286.7) than in the mobile version (M = 205.05). Lastly, the T-test result shows that the active users in Group A have solved a smaller number of towers (M = 5.85, SD= 1.99) compared to those in group W (M = 8.67, SD = 1.66). Additionally, the assumptions of homogeneity of variances were tested and satisfied via Levene's F-test, F (22) = 0.607, p = 0.444. The independent samples T-test was associated with a statistically significant effect, t (22) = -3.76, p < 0.001. Thus, there is a difference between the number of towers created by active users in Group A, and W. Cohen's D was estimated at 1.53, which is a considerable effect size based on Cohen's (1992) guidelines.

4.1.4 User Experience

From our post-study questionnaire, we found that the participants like to answer the questions more in the web version of the game than in the mobile app version. When asked, "Which feature(s) did you like in the game?", those in the web-version group responded, "Attacking towers". The mean and median for towers solved by active users are higher in group W than in group A and the statistical test report shows that participants prefer to use the web version while solving the question over the mobile version. The reason for using the web version could be that the students can see and understand the problem better when using the web version. For example, if a student posts a lengthy MCQ question, it is easy to read the question and compare the options in the web version. In the mobile version, the students must remember all choices to compare them, which could result in a cognitive overload for the student. Another reason might be that when answering questions, it was easier to consult the course materials on the web than using an app.

Furthermore, the students rated the version of the game they used, but unfortunately, only a small number of participants completed the questionnaire. The statistic shows that 43.47% of participants from group A and 53.52% of users from group W rated the game. The average rating for the application version is 3.65, whereas for the web version, 3.86 out of 5 (Figure 13). Most of the participants in our study rated both versions of the game with an average of above 3.5 on a scale of 5. This result also shows that both versions of the game were rated favourably.

5. Discussion and conclusion

In this paper, we investigated the effectiveness of application-based and web-based versions of the educational game Tower of Question (ToQ) (Kiron and Vassileva, 2018) in engaging students by evaluating the two versions in parallel within one class and comparing the results from both versions. The result shows that there is no significant difference between both versions of the game. Both versions have almost the same functionalities, such as posting a new question, gaining points (gems), and solving the questions posted by other users in the system.

The only differences between the two versions were in the interface design, the aesthetics, the implementation platform, and the presence flagging feature in the web version. The application version had a more vibrant colour than the web version. We employed a quantitative approach to collect data to determine which version

is more effective in game-based learning by using the Mann-Whitney U test to match the perspective of this study. The data analysis provided the answer to the research question, "Is there a difference between the effectiveness of the two versions in engaging students and if there is, which version is more effective?". The evaluation of the game-based tools shows no significant difference between the two versions in the number of active users (one of the engagement measures used). However, there were significant differences between the student's engagement in the two-game versions in terms of creating questions and answering questions. The students were significantly more engaged in creating new questions (towers) in the mobile application version and more engaged in answering questions (attacking towers) in the web version. Thus, in both implementation platforms, the game can engage students and increase learning through practice. Both versions of game-based learning are helpful by providing value to the user and helping them achieve their goal of practicing their course materials. Other research also supports these findings, such as business/ marketing (Ding, Guan and Yu, 2017; Zakaria *et al.*, 2018), education/learning (Barata *et al.*, 2013; Ding, Er and Orey, 2018; Rachels and Rockinson-Szapkiw, 2018), health/work out (Calle-Bustos *et al.*, 2017; Kostenius, Hallberg and Lindqvist, 2018; Rajani, Mastellos and Filippidis, 2021). One recommendation resulting from our work for designers would be to create and maintain two versions (both web-based and mobile app) of educational games so students can use both simultaneously to increase engagement in different activities.

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Marie's ChemLab: A Mobile Augmented Reality Game to Teach Basic Chemistry to Children

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Abstract: Digital games are widely used in education to motivate students for science. In parallel, the role of augmented reality (AR) in education is increasing. This paper introduces Marie's ChemLab: a marker-less handheld AR application in which K-12 students learn about science. In Marie's ChemLab, users perform interactions in their physical environment using virtual AR objects displayed on a handheld device. The utilized interaction concept is based on the TrainAR framework (Blattgerste et al, 2021), which originally was envisioned for procedural AR training and layered feedback mechanisms. The original framework has been enhanced to support gamified interactions with virtual objects, specifically for K-12 students. In total, 239 early secondary school students played the final application as part of a larger study. The usability score indicated marginally acceptable usability, and the application was successfully implemented in a classroom setting.

Keywords: mobile augmented reality, simulation games, science education, SUS

1. Introduction

Students' interest to engage in academic content in compulsory education declines with age (Shin et al, 2019). Particularly, STEM (Science, Technology, Engineering, Mathematics) subjects are characterized as the least popular among a broad range of students (Renninger et al, 2015). Digital games have been proven effective as an approach to increase students' motivation (Lamb et al, 2018; Arztmann et al, 2022) through their typical characteristics such as providing a feeling of relatedness, autonomy, and competence (Ryan & Rigby, 2020). Augmented Reality (AR) provides an opportunity to create games that offer embodied interactions and immersive visualizations that elicit learning benefits (Hung et al, 2017; Radu 2014). With the increasing availability of smartphones and tablets that are capable of deploying AR scenarios, it also creates the opportunity to implement AR applications in classrooms easily. However, the implementation of newer technologies into classroom settings is still a challenge due to, e.g., themes not matching the classroom's curricula (Poultsakis et al, 2021), accessibility, and cost factors (Blattgerste et al, 2021).

AR for handheld devices allows for immersive visualizations and simulation of concepts using engaging interaction metaphors, like on-screen touches, smartphone translation, and rotation or spatial proximity triggers, that require more embodied interactions than conventional approaches. However, research on using AR in classroom settings thus far has been scarce and has mostly focused on visualization aspects, with very little or no interaction. It is now clear that AR enables the development of simulation games that help students better understand complex phenomena through not only contextualized 3D visualizations but also the freedom to choose their own viewing angle and focus. But what about the possibility of interaction with and exploration of physical environments enriched with 3D content? This would not only be particularly useful for situations that are hard to study in a traditional classroom setting but might also have an effect on the immersion and subsequent motivational factors of the students. As thus far, most AR applications have been developed for visualization purposes only (Dominguez Alfaro & Van Puyvelde, 2021), which offer little to no interactivity, and

available approaches have hardly been validated for learning (Arztmann et al, 2022); we introduce Marie's ChemLab: a mobile AR game to teach basic chemistry to children.

This paper describes the design of the game, including the adjustments that have been made to make it suitable for a young target group, and studies the game's usability and feasibility of implementing it in a classroom environment.

2. Marie's ChemLab

Marie's ChemLab is a marker-less handheld AR, single-player game designed for tablets. The game consists of three sequential levels, situated in different scenarios (kitchen, forest, and lab). Each level introduces a student to a different chemical concept, and they are asked to complete various tasks to advance in the levels. To help guide a student, an intelligent agent (Marie, "the expert") provides messages on essential things to look at, try or remember (Figure 1a). At the end of each level, the game shows post-it notes with essential concepts to internalize (Figure 1b).



Figure 1: a) Introductory scene of Marie "the expert"; b) example end post-it note from level 2

The game starts on level one ("Fruit Salad") (Figure 2a). The scenario is located in a kitchen with different fruits to be tested. The main goal is to compare the acidity of three fruits and associate their "sourness" with the level of acidity. A student starts by ranking the fruits in three bowls: "sour," "less sour," and "sweet." Afterward, a toolbox appears with different tools such as a hammer, a bubble pump, and a box with pH paper. All of these tools can be explored. If the students are successful, they discover that with the help of the hammer, they can cut the ranked fruits and measure the pH with the pH paper. Finally, the player can observe the discoloration of the paper and rank again according to the sourness of each fruit in the three bowls.

In level two ("Smoothie party"), the student is in a forest (Figure 2b). The scenario displays a bush full of blackberries of different ripeness. Marie is also there. The level starts when the user feeds Marie with each of the berries. Depending on the berry's ripeness, she reacts with a sour, happy (sweet), or neutral face. Marie's reaction aims to clarify that each berry has different acid and sugar content. Afterward, the student prepares some juice of unripe berries and compares the difference when lime is added to this juice and juice made of sweet berries. Finally, the student learns that blackberry juice changes color when lemon/lime is added; thus, it can be used as an indicator.

The game ends with level 3 ("Kitchen Detectives") (Figure 2c). The scenario is located in a laboratory, where the pH of three different kitchen products needs to be measured and ranked accordingly. The student can measure the pH using the tools they learned about in levels one (pH paper) and two (blackberry juice).



a) Fruit Salad b) Smoothie Party c) Kitchen Detectives

Figure 2: Marie's ChemLab Levels

2.1 Development and Design

Marie's ChemLab was designed and developed using the User-Centered Design (UCD) approach and the Design Implementation Framework (DIF) (Stone et al, 2018). Thus, usability indicators and feedback from the students are integrated iteratively to improve the application.

Additionally, Marie's ChemLab was designed with the aim of triggering students' interest in chemistry by providing a playful environment with relatable content. By adding game mechanics intended to satisfy students' need for autonomy, relatedness, and competence (e.g., cue messages at the top of the screen; Ryan & Rigby, 2020) we intended to create a game environment that sparks students' interest for chemistry, which would be based on the first phase of the four-phase-interest development model by Hidi & Renninger (2006). As such, interest may develop from brief situational interest to maintained-situational and emerging-individual interest, given that students are provided with additional opportunities to engage with this topic by their teachers or their individual environment.

2.2 Learning goals

Each level introduces a different learning goal with the provided content. In level one, students should develop a basic understanding of sourness and that sourness can be measured by the use of pH-strips. Level two builds upon these concepts and introduces a natural indicator as an alternative to the pH strips. Finally, level three is aimed at transferring the learned content of measuring other materials with the various tools introduced to different tools that can be measured, showing that also fluids that are found in the kitchen can be acidic.

The iterative process began with several content ideation sessions with secondary and primary school teachers. The idea was to create levels that are based on young students' experiences and, therefore, can easily be connected to basic concepts of daily life chemistry. As such, the topic of acidity was chosen. It is important to create a basic understanding of the term acidity, which forms the basis of understanding pH values and, in further education, the basis of titration experiments. A three-level structure was chosen for the game to divide the concept of acidity into sub-concepts. This structure and each of the levels were based on a real classroom intervention for the topic, thus the game follows the format of an existing lesson plan which was provided by a teacher. This ensures comparable results of the intervention and allows teachers to integrate the application into their curriculum more easily.

2.3 Iteration and prototyping

A first digital prototype was developed using the TrainAR framework (Blattgerste et al, 2021). TrainAR is an interaction framework with an authoring tool, in which interactive procedural task training applications can be developed. The user of the prototype can interact with objects that elicit feedback to the user's actions. The user can grab, release, interact and combine virtual objects to advance in each level.

The original TrainAR framework was developed with procedural tasks in mind. It can also be used to create games that follow a rule-based approach without enforcing a particular order on the rules. Marie's ChemLab is a rule-based game where the user must accomplish a set of defined goals at each level. Therefore, the user can explore the environment and freely decide on the sequence of actions. They are guided on each level with messages given by the expert (Figure 3a), pointers at the top of the screen (Figure 3b), and layered feedback (sound and outlines) embedded in the system (Figure 3c).

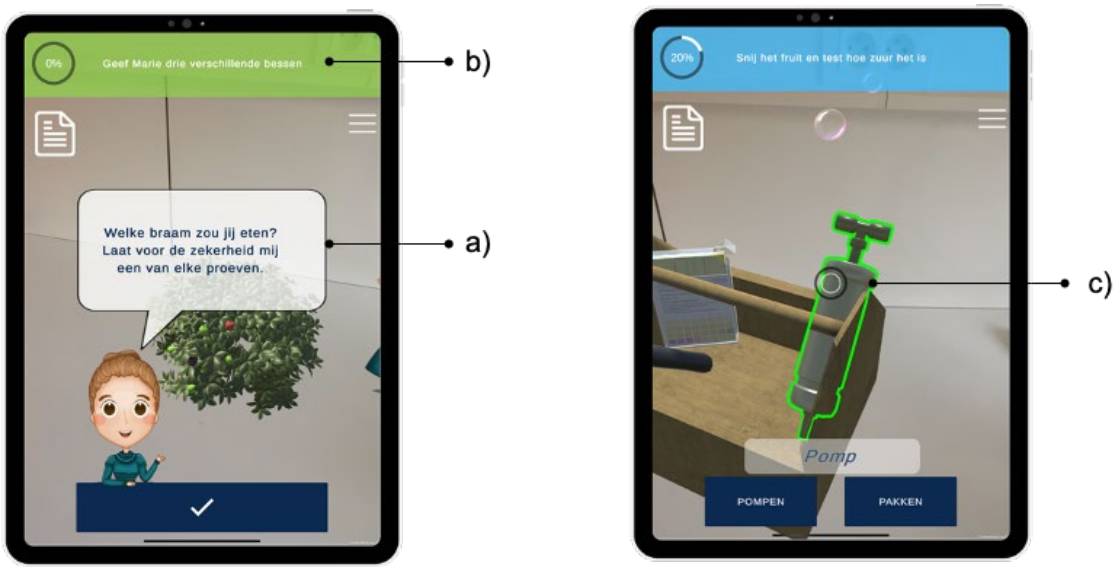


Figure 3: Design elements: a) message given by Marie in level 2 (the intelligent agent); b) on-screen pointers; c) example of object outline

A first prototype was evaluated in two non-representative preliminary small-scale pilots with students in 5th grade. Based on observations and their feedback, the prototype was adjusted to the final version used for the evaluation of this paper. Particularly, changes concerning challenges with the position and size of the interaction button (Figure 4) and the structure of the tutorial were addressed.

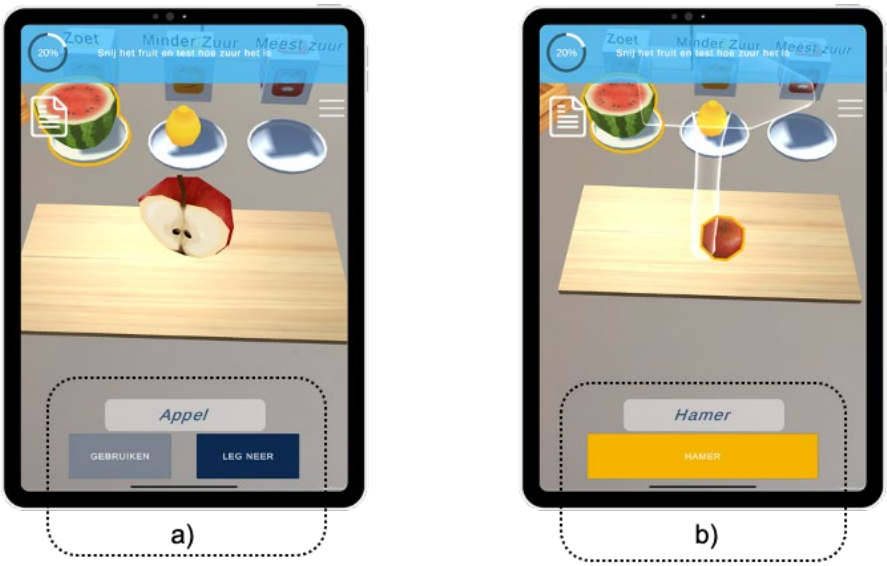


Figure 4: a) two interaction buttons showing the option to “use” or “release” the object (apple); b) when an interaction between two objects is possible, the combine button appears as one single yellow button.

2.4 Playtesting

As part of a larger study, 239 year 1 and 2 students (M_{age} = 12.9, SD = 0.8) from Dutch secondary schools played the game in one of their science lessons. The game was played on iOS tablets (iPad 9) that were provided by the researchers. The students had 30 minutes to play the game; after that the game automatically moved them to

the post-test. In case students finished early, they were provided with riddles that they could solve until their classmates completed the game. To measure usability, the adapted version of the System Usability Scales (SUS) for children introduced by Putnam et al (2020) was used. To create a Dutch version, the back-translation method was applied. The Dutch items can be found in the Appendix. Ethical approval for this study has been granted by the local Institutional Review Board.

3. Evaluation results

3.1 Classroom implementation

Even though the students had 30 minutes to play the game before they were moved to the post-test, the majority needed less time and were able to finish with the last level within 20 minutes. None of the students communicated complaints about the device being too heavy, and no apparent problems with properly holding tablets while playing the applications could be observed. All students were able to play the game simultaneously. The researchers were mainly available to answer questions regarding possible technical issues. Additionally, they would intervene when the scene was placed too far away (i.e., on the ground instead of the table) or when a glitch of the application was experienced.

3.2 Usability

When analyzing the perceived usability through SUS scores using the SUS Analysis Toolkit by Blattgerste et al (2022), the overall SUS score of Maries' ChemLab was 54.7 (SD = 15.19). This result would indicate "OK" usability and be contextualized in the first quartile of SUS scores gathered in meta-analysis datasets, according to Bangor et al (2009). According to Bangor et al (2008), this usability score is still marginally acceptable. When grouping the SUS scores by age, these results stay persistent. As visualized in Figure 5, the n = 77 students aged 11 to 12 reported an average SUS score of 54.16 (SD = 15.19), the n = 110 students aged 13 reported an average SUS score of 54.34 (SD = 17.09), and the remaining 52 students that were aged 14-15 reported an average score of 56.25 (SD = 13.53). All scores would still indicate "OK" usability, be contextualized in the first quartile of SUS scores, and be marginally acceptable. While there is a slight upward trend observable, where usability scores increase with the age group, a one-way ANOVA revealed that there was no statistically significant difference in reported perceived usability through the SUS scores based on the participants' age groups (F(161.638, 58707.472) = [0.324], p = 0.723).



Figure 5: The SUS scores of the evaluation of Marie's ChemLab, grouped by age, contextualized on the adjective scale by Bangor et al (2009). Dotted lines show the mean and SD, box plots show the median, quartiles and all data points besides the plot.

For the original SUS questionnaire by Brooke (1996), 100% conclusive results can be reached with around 14 SUS scores per SUS study score. While we used a translation of a variant of the questionnaire by Putnam et al (2020), the sample size of n = 236 should yield conclusive results, according to Tullis et al (2004). Nonetheless,the

adjusted SUS scale showed a rather low internal reliability, with a Cronbach's alpha of .446. Since the proposed variation of Putnam et al (2020) failed to establish full construct validity, the results need to be interpreted with caution.

4. Discussion

AR provides the opportunity to create game environments that offer embodied interactions and immersive visualizations that can increase the learning and motivation of students. As AR applications thus far have mainly been developed for visualization purposes only and have not added interactivity, Marie's ChemLab was designed to be easily used in a school environment by combining both visualization and interactivity and using accessible hardware for implementation. Additionally, it aimed to provide a first impression of daily life chemistry that should trigger interest in students.

This paper shows that AR technology can be successfully implemented in a classroom. The perceived usability of the game with a SUS study score of 54.7 (SD = 15.19), however, can be improved. The observed results of the adapted SUS need to be interpreted with caution, since the scale failed to reach a sufficient reliability score. Different from the adjusted version of Putnam (2020), the reliability was calculated for the overall scale and not in different dimensions. Additionally, our target group was older than the original age group used to validate the children's version. Nevertheless, our results could be in agreement with Radu's (2016) findings, which showed that children of different ages encounter different usability issues with handheld AR such as inaccuracy in interacting with objects in the virtual environment or difficulties in remembering the spatial locations of virtual objects. A possible explanation for this might be that in Marie's ChemLab, the students are required to aim the crosshair at a specific object. This interaction may be problematic for some students since it requires an understanding of the spatial relationship between the two-dimensional projection of the device and the real environment. (Radu et al, 2016).

5. Conclusions

This paper makes three contributions. First, Marie's ChemLabs design rationale and the didactic considerations during its development were described. Secondly, details of the application with its three levels and the changes that were made during development were reported. Finally, Marie's ChemLab was evaluated with 239 students from Dutch secondary schools spanning year 1 and 2, with a focus on the perceived usability and potential of interactive handheld AR games in this context. The results showed that although the usability of Marie's ChemLab can be improved, the game can successfully be used in a real classroom setting. This can show interested practitioners and researchers that students are able to play through the levels of Marie's ChemLab independently and can interact with the application at their own pace. Moreover, in case of implementation, the teacher would only need to be available to answer possible questions.

Further improvements of Marie's ChemLab can be focused on adding an adaptive system that provides instructions based on the student's individual abilities. In spite of its limitations, the study certainly adds to our understanding of the use of interactive games in AR.

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Appendix

Table 1: Overview including the original SUS items, the adapted children's version and the Dutch translation.

Original SUS by Brooke (1996)	**Adapted SUS for children by Putnam et al (2020)**	**Dutch translation of the adapted SUS for children**
I think that I would like to use this system frequently.	If I had this app on my iPad, I think that I would like to play it a lot.	Als ik deze app op mijn iPad had, zou ik het vaak spelen.
I found the system unnecessarily complex.	I was confused many times when I was playing this app.	Tijdens het spelen van de app was ik vaak in de war.
I thought this system was easy to use.	I thought this app was easy to use.	Ik denk dat de app makkelijk te gebruiken is.

Original SUS by Brooke (1996)	**Adapted SUS for children by Putnam et al (2020)**	**Dutch translation of the adapted SUS for children**
I think that I would need the support of a technical person to be able to use this system.	I would need help from an adult to continue to play this app.	Ik zou hulp van een volwassene nodig hebben om deze app te spelen.
I found the various functions in this system were well integrated.	I always felt like I knew what to do next when I played this app.	Tijdens het spelen van de app wist ik hoe ik verder moest.
I thought there was too much inconsistency in this system.	Some of the things I had to do when playing this app did not make sense.	Sommige dingen die ik in de app moest doen, begreep ik niet.
I would imagine that most people would learn to use this system very quickly.	I think most of my friends could learn to play this app very quickly.	Ik denk dat de meeste van mijn vrienden snel zouden leren hoe zij de app moeten spelen.
I found this system very cumbersome to use.	Some of the things I had to do to play this app were kind of weird.	Sommige dingen die ik tijdens het spelen van de app moest doen, waren raar.
I felt very confident using this system.	I was confident when I was playing this app.	Ik had zelfvertrouwen tijdens het spelen van de app.
I needed to learn a lot of things before I could get going with this system.	I had to learn a lot of things before playing this app well.	Ik moest veel leren voor ik de app goed kon spelen.

Using Game-based Learning Methods to Demystify Cyber Security Concepts for Adult Learners

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Abstract: The digital society we live in today has compelled both businesses and individuals to become increasingly dependent on the internet and online services. With the increasing cyber security threats and attacks, there is a growing demand for cyber security professionals and a need for every individual to be cyber literate and cyber-aware. But cyber security is often regarded as extremely complex and quite technical, which acts as a roadblock in educating the adult population about cyber security. 'Play as a natural means for learning' is commonly exploited in early learning and primary education settings. But it is seldom used in secondary education and rarely considered in an adult learning context. This paper presents a game-based learning resource developed as part of the 'Gamified Intelligent Cyber Aptitude and Skills Training' (GICAST) course to introduce cyber security topics to adult learners. The course is targeted at adult learners who work in low-skilled and low-paid jobs and have no formal degree-level qualification. The aim was to demystify cyber security concepts and equip the low-confidence learners with the confidence to engage in learning and gain additional digital skills to enhance their career options. This paper provides an overview of the GICAST project, the game design principles and the game mechanic employed to achieve the intended pedagogic outcomes. The paper illustrates how the power of games helped demystify a complex area of cyber security among adult learners. This is demonstrated in the evaluation results and findings from the study on the effectiveness of game-based learning methods in enhancing learner engagement and motivation to learn among adult learners.

Keywords: game-based learning; cybergames; adult learning; game design; upskill

1. Background Context

The findings of the cyber-security skills in the UK labour market report by the Department for Digital, Culture, Media & Sport (DCMS) conducted in 2022 indicated an acute shortage of cyber-security professionals in UK following a similar global trend (DCMS, 2022). On the one hand, demand for cyber security professionals is on the rise; on the other hand, COVID-19 has created a substantial economic shock, with millions facing severe threats to their jobs, both immediately and in the longer term. Low-paid workers, particularly those in the sectors that could be displaced by automation, are at risk (Nesta, 2021).

There is a need to boost retraining efforts to address the immediate cyber security skills shortage and bring a diverse range of skills and experiences into the sector. The government has put in strategic measures to address this challenge through its cyber security skills strategy (HM Government, 2022) to widen participation and boost equality and diversity in cyber security careers, mainly by removing barriers to entry and progress for poorly served groups. It is in this context that 'Gamified Intelligent Cyber Aptitude and Skills Training (GICAST)' was funded by the department for education (DfE)and Nesta to develop a game-based learning resource. It was targeted at the low-confidence learners with no formal degree-level qualification, aged between 24-65 years and employed in sectors vulnerable to displacement such as manufacturing, hospitality etc.

GICAST[1] is a badged open course (BOC) hosted on Open Learn Platform[2] a MOOC platform. The course consists of eight units of study with 24 hours of learning spread across eight weeks. Each unit of study covers a foundational aspect of cyber security for learners to gain fundamental knowledge and an understanding of online safety. Each week, the learning on GICAST begins with a game that the learners play prior to continuing their learning. The games are designed to elicit intuitive responses reflecting the actual action or reaction of the learner in a real-world setting, which helps assess the learner's current security behaviour. In addition, the in-

[1] https://www.open.edu/openlearn/science-maths-technology/gamified-intelligent-cyber-aptitude-and-skills-training-gicast/content-section-overview?active-tab=description-tab
[2] https://www.open.edu/openlearn/

game quiz assesses the learner's current knowledge, based on which the learners are directed to an adapted learning pathway. The pathway recommendation is intended to optimise the learner's journey through the course, ensuring they do not spend time on concepts they are already aware of. GICAST did not enforce the recommended adapted learning pathway on the learners, who were free to navigate through the entire content at their own pace and in the order of their preference.

The game-based learning methods employed in the project intend to promote active learning experiences among adult learners and equip them with the confidence to gain additional digital skills to enhance their career options. In this effort, it was essential to demystify a complex area of cyber security for adult learners. This study aims to demonstrate the effects of game-based learning methods on adult learners, particularly their motivation to learn a new skill and enhanced engagement to complete their learning. Section 2 presents a brief literature review on current research that addresses the barriers to learning among adult learners and how game-based learning methods could potentially address any gaps. Section 3 presents the game design and implementation of cyber security game-based learning resources for adult learners. Furthermore, section 4 presents the evaluation methods employed and key findings, and the paper concludes with the key inferences and learning from the project.

2. Related Work

E-learning is the most common delivery method for workforce development and workplace learning (Githens, 2007). Several barriers to learning in the adult learning context hamper them from fully engaging in the e-learning programs. Past negative learning experiences, lack of confidence in using digital technologies and returning to learning after several years of gap demotivates the adult learners from fully engaging in learning and from completing their learning journey.

Two key challenges for educators creating content for adult learners is intrinsic motivation and engagement (Kim, 2009). While game-based learning methods are commonly used in primary and secondary education settings quite successfully Huizenga et al (2009), they are rarely considered in the adult education context, particularly for upskilling the adult population, as with the GICAST project. We will present the work and findings related to game-based learning methods used in adult learning context in the following subsection.

Engagement has been identified as a significant issue with existing training methods to introduce cyber security to adult learners (Reeves, Calic & Delfabbro, 2021; Bada, Sasse & Nurse, 2019). Games, and in particular video games, are known for being engaging activities. Hamari et al. (2016) finds a positive correlation between challenge within game-based learning and the engagement of participants, which further correlates to perceived learning. Ejsing-Duun (2014) concluded that the playful approach in higher education demonstrates that game-based methods allow students' intrinsic motivation towards deep learning while enhancing participation and engagement if balanced with the formal curriculum. Furthermore, reports such as the NMC Horizon Report (Johnson et al., 2014) indicate that educational gameplay has nurtured engagement, critical thinking, creative problem-solving, and motivation to learn. Hence a close look at the various game-based methods will help ensure the right approach is considered to achieve significant results in enhancing engagement and motivation to learn amongst adult learners. A particularly important concept that relates to engagement is that of flow. Flow is a state of in- creased focus, immersion and efficacy, brought about by a suitably engaging activity (Csikszent- mihalyi, 1990). There have been numerous studies into flow, and it’s impacts on engagement, learning, immersion and enjoyment. Webster, Trevino & Ryan (1993) provide evidence suggesting that flow has a positive impact on learning and help increased engagement with learning.

Challenge is a nother 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.

An effective cyber security training is interactive (Reeves et al., 2021), and games are usually interactive. A notable advantage of game-based cyber security training is the engagement factor of games, which can also increase motivation to learn (Zhang-Kennedy & Chiasson, 2022). A significant number of game-based cyber security training uses some form of simulation and virtual game world in 2D or 3D (Hendrix et al.,2016)

CyberCEIGE (Irvine, 2011) is a popular simulation-based game that involves simulating a real-world cyber situation, where the learner plays a decision-maker for an organisation.

Another simulation-based game, Anti-Phishing Phil (Sheng *et al.*, 2007), involves sending simulated phishing emails in which the player must decide whether the email is a phishing attempt.

The use of games has been considered in training adult population in cyber security. 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. Hence, we are unable to infer strongly about the effectiveness of game-based methods within the adult learning context. However, there are studies demonstrating the effectiveness of game-based methods in improving engagement and flow among adult learners. In this project, we have designed the games to impart engagement and flow, to demystify a complex subject area such as cyber security and enhance learner experience.

3. Game Design and Development

3.1 Game Design principles

Educational games are often criticised for not integrating learning and gameplay in a balanced way. The learners are either distracted by the gameplay part of a poorly designed game which hinders them from achieving the intended learning outcome and or become disengaged with learning when the learning elements interfere with or corrupt what is enjoyable about the game-based resource (Ke et al., 2019). Therefore, a poor design of game-based learning resources may be counter-productive and a hurdle for learning.

The gameplay constructs within GICAST were designed to include two layers; the narrative layer that employed story-based scenarios and the game mechanics layer that included the rules and actions that governed the narrative. According to Salen and Zimmerman (2005), the gameplay lies in the meaningful interplay between the two layers.

In the context of this project, game-based learning methods were employed to help lower the barriers to learning among the low-confidence adult learners. They may have past negative learning experiences and conscious bias against cyber-security as a highly complex topic to learn. Therefore, it was essential to keep the game mechanics and rules of gameplay simple and not add further barriers while tapping into the power of story-based narratives to make the content relatable to the learners. Many games have a narrative aspiration or tap into the player's memory of previous narrative experiences. The story-based narrative is integrated into the GICAST games in the following three ways:

- as a background plot or mission,
- a localised incident or plot developed within the game-levels
- Partially included the concept of open-ended gameplay by allowing the learners to create their narratives based on the decisions they make during the game.

Each game was designed with a particular narrative; the story behind the game provided the context and link to a specific topic in cyber security. While some games provided a direct link to cyber security concepts, the others were indirect. The games were designed with three types of a narrative (story):

- analogy driven scenario (a parallel between a cyber world and the real world),
- real-life scenarios that involved cyber security decisions we make every day, and
- concepts-driven story.

The final game intended to assess the learner's knowledge and overall learning within the course were based on pure gameplay based on a 'shooting' game mechanic. The design of games used grotesque and fun/humour elements to support engagement and improve knowledge retention, which aligns with findings from previous studies that indicate story-based engagements are known pedagogically to support knowledge retention (Dickey, 2020) (Wouters & Oostendorp, 2013). The elements of 'grotesque' offered an interesting approach to authenticity. The project timeframe and the budget did not allow for high-end visualisation and immersive graphics. Minecraft-style design set the learner's expectation for those from a gaming background that the focus was on narrative and game-logic rather than the visual gaming experience.

3.2 Development of Game-based learning resources

3.2.1 Core Game logic

GICAST is a self-directed badged open course hosted on the Open Learn MOOC platform. GICAST was designed to be Self-directed as students found that the participants benefited from a sense of autonomy and control over the pace and duration of learning when self-directed theory is embedded within game-based learning (Vanduhe, Nat, & Hasan, 2020). This also aligns with works from researchers in adult learning, who highlighted the need for autonomy and the influence of motivation in their learning process (Albert & Hallowel, 2013). GICAST consisted of eight units of study spread across eight weeks with study intensity of three hours per week. Each week, the course begins with a mini-game, built-in mine-craft style 2.5D visual effect. According to the researchers (Smith & Sanchez, 2010), the ability to deliver different types of information through short, interactive sessions such as mini-games could position them as a viable teaching method. The digital mini-games were particularly effective in GICAST as the adult learners were taking the upskilling course on GICAST by investing additional time and energy beyond their professional and personal commitments. The bite-sized learning helped them cope with the study workload amidst personal commitments. In addition, many educational digital games were designed with real-world context and authentic tasks (Sanchez et al., 2010). The mini-games were based on real-world context and analogy-driven scenarios that allowed the learners to anchor new and complex information delivered as part of GICAST with their prior experiences, which is crucial when working with professionals in an upskilling course (Tay et al., 2022).

Learners played the mini-game at the start of each week's study, which helped assess their current knowledge and understanding of the topics covered in the respective unit of study for the week. The game assessed the learner's current knowledge by taking the learners through a story-based narrative within the game using the in-game stealth assessment method based on previous work by Shute and Ventura (2013). Assessing participants' knowledge is difficult through a self-assessed survey, as answers may not be accurate, reliable, or devoid of bias (Shute & Ventura, 2013). The mini-games embedded as GICAST were well suited to integrating stealth assessment and other performance-based assessment methods, allowing a more reliable measure of the learner's current knowledge and skill level.

The game mechanic within the mini-games was designed to elicit intuitive responses from the learners for various real-life scenarios embedded as part of the gameplay. The intuitive responses of the learners were then compared with the baseline good security practices, and the learners were marked based on how much their responses deviated from the expected good security practices. The assumption made by the game logic is that the deviation of the learner's response from the expected good security practice was directly proportional to the gap in the learner's current knowledge and understanding. At the end of each game, the learners received feedback on their performance and were directed to one of the two learning pathways that were personalised and adapted to suit the needs of the learner.

- the green pathway was a fast-track learning route which was curated for the learners who demonstrated a good understanding of the topics covered in the week through their performance in the game,
- the amber pathway was a regular track that was curated for learners who demonstrated knowledge gaps as part of the assessment in the game.

However, the adapted learning pathways were not enforced on the learners, and they could choose the pace and sequence of their study to suit their own needs.

3.2.2 Pedagogic intent and Game Mechanics

Game-based learning resources involve the integration of education and learning processes. The key metric to measure the impact of game-based learning resource is the learning effectiveness; learner engagement and learner motivation are two key requirements for learning effectiveness. The game design methodology as discussed in the previous section considered these two key factors, in addition to other factors such as the usability of the game, which is dependent on several other game-related factors(Balakrishna, 2021). The instructional element of the game consisted of the pedagogic intent and the intended learning outcomes, while the gaming element consisted of the game mechanic chosen to suit the pedagogic intent of the game.

Story-based narratives and role-play was used across all the eight games in addition to specific game mechanics to suit the learning content. Story-based narrative and role-play attributes of game-based learning methods lend themselves naturally to security awareness training

Story-based Games allow players to experience events and scenarios through a narrative and the use of characters (avatar/role play) is known to influence behaviour and effective for skills training (Balakrishna, 2021). In addition, use of narrative creates a bond between the learner and the avatar and reinforces the learning.

4. Evaluation and Results

Theory of change was methodology used for evaluation of the impact in this project. The theory of change has been used in many contexts and there are many examples of how the approach can be used (**John Mayne,**

2015)**.** Participatory evaluation is generally used to assess micro-level impacts that is often qualitative in nature but can also involve quantitative methods. The participants were given a questionnaire, this is optional, prior to the start of the course and again on completion of the learning. There were also weekly quizzes and intermediary knowledge checks embedded as part of the eight-week course.

There were additional incentives that should be considered, such as if the learners completed the learning within a eight weeks, the learners were given access to free cisco certification training (Cyber essentials and cyber Ops). There was also the opportunity to compare some of the findings against the previous course that didn't benefit from game-based designed learning.

The scope of the evaluation was limited to evaluating the two main outcomes, namely, increased learner engagement and positive learner experience (implied motivation to learn). The evaluation aimed to test whether the planned outcomes were achieved as intended and understand factors that contributed to the results and identify the barriers.

The evaluation questions were derived from the project's theory of change. While the details of the theory of change methodology is out of scope, what is relevant in the context of this paper is the following:

The two questions that address the evaluation of GICAST's objectives/outcomes are:

1. What role does game-based methods play in the learner experience of online learning on GICAST?
2. What aspects of the game design are most effective in engaging the target audience?

Two major outcomes selected as the focus of the evaluation activities are: learner experience and learner engagement. Other outcomes that we considered as part of the project such as career adaptability and confidence in digital learning is out of scope for this paper.

The main evaluation methods used were:

- Collection of participant information on learner demographics, job vulnerability, attitudes towards and experience of learning, use of technology, previous gaming experience, level of digital skills, knowledge of and view of cybersecurity, motivation to learn on GICAST **(pre-survey)**.
- Collection of participant information on the factors that benefited (or not) their learning experience and engagement including any change to attitudes to learning, use of technology, view of cybersecurity, motivation to continue the learning journey, career adaptability **(post-survey)**
- Qualitative data was gathered through focus group discussions

4.1 Methodology and Data Collection

GICAST had access to both qualitative and quantitative data. A mixed methodology of the evaluation took place. Triangulation of the data to interpret the outputs of the data was used to see what factors of impact, good or bad could be considered. The following approach was used for data collection: Pre and post course survey; two focus groups both before and after the completion of the course; data from the Open Learn analytics- such as time spent on games, how long users were taking to complete the course; data from the quizzes

4.1.1 Participant recruitment

All data was anonymised and the surveys, focus group discussions and quizzes were all optional for participants. The recruitment of participants was achieved through the project partners stay nimble (Stay nimble, 2018) and Department for Work and Pensions(DWP) that helped reach the community of learners that the GICAST was intended for. The demography can be described as learners that did not have a degree-level qualification, employed in low-paid/low-skilled jobs and were at risk of losing their job (vulnerable) and aged between 24 to

65. To analyse the outcomes measures from the pre and post surveys, the sample was first restricted to remove participants who did not meet the programme eligibility criteria. Once ineligible responses had been removed, there were 177 pre-survey responses and 167 post-survey responses.

4.2 Key Findings

4.2.1 Learner Engagement

- 20.8% of learners enrolled to the GICAST course completed the course within the first three months of launch. This is double the percentage of learners completing the traditional badged open courses without any game-based methods. This compares well with a median value of course completions at 12.9% from an independent study done earlier (Jordan, 2015).
- Average time learners took to complete GICAST course is 27.98 days which is 4 weeks of learning, while the course was designed for study intensity of 3 hours a week spread across 8 weeks. This is in comparison to the average time learners took to complete a similar course without game-based methods was 67.98 days, which was 8 weeks. This is further substantiated by post course survey, where 68% of GICAST learners have indicated to have spent more than 3 hours a week on learning while only 38% of learners on the old course indicated to have spent more than 3 hours on learning.

The above statistics indicate, there has been increased engagement with the GICAST content and the learners have spent more time learning than learners on the old course and in comparison, to what was anticipated by the course designers.

4.2.2 Engagement with games and quizzes

Qualitative data analysis shows that games played an essential role in supporting most learners' engagement. The post-survey and focus group analysis revealed that the learners found the following aspects particularly engaging:

- *Experiential learning* - being able to take part in an action happening in a virtual scenario rather than just reading the course content:

"the weak and strong passwords showed that having different passwords in different services is more secure - the physical representation of the game, and engaging with it for me was more enlightening than simply just reading it"

[Survey respondent in reply to a question 'Why did you like those games most?']

- *Relevance* - a context that the learners can relate to and recognise in their own life *"The "Hidden Connections" game helps me identify some bad choices I used to make – using free WIFI, being careless with confidential information in a public place, and divulging personal information indiscriminately."*
- *Decision-making* – questions embedded in the games to elicit decisions were seen as engaging, clicking to follow the action less so:

"Most engaging were the ones where I actually had to do something with my brain rather than following the action. So quite a few of them."

Overall, 71% of survey respondents felt that the fun element of the games helped them engage more with the course.

A minority of post-survey respondents (3.16%) did not engage in the games, and 13.29% felt they gained nothing from the games. 10 out of 84 who replied to a question:
'Are there any games you didn't like, if yes please tell us why', did not find the games engaging either due to the quality of graphics or confusing storyline.

"I found their presentation "clunky" and old-fashioned"

4.2.3 Learner Experience

Learners were generally very positive about the course. 94.51% of post-survey respondents enjoyed learning on the course, 90.51% were either quite or very satisfied with their learning experience, and 84.66% agreed or strongly agreed that studying the course was fun.

The responses to the question '*Please describe your favourite part of the course'* varied with learners appreciating the course structure, variety of content, or topics of interest. Overall, games have received the most mentions (35 out of 106), followed by quizzes (20).

These statistics as well as the data gathered on the post-course survey on the games indicate that the games played a large part in enhancing the learning experience of the learners.

- 74% of learners felt 'Games helped me understand cyber security concepts and practices '
- 66% of learners felt 'What I learned in the games helped my understanding of other learning resources'
- 77% of learners indicated 'Analogy-driven scenarios helped me remember key cyber security concepts and practices'
- 71% of learners felt 'I feel that the fun element of the games helped me engage more with the course'
- 70% of learners indicated 'The timed activities in the games helped me focus and stay on task'

5. Conclusion

The findings indicate that the games achieved their purpose in engaging the target audience and in turn overall learning experience of the learners and motivation to complete the course. The minority of learners who did not find the game component appealing or useful could skip them with no negative consequences to their learning since the games were an additional rather than core component of the course content. What was particularly engaging about the games was the hands-on action and decision-making in familiar scenarios and elements of fun/grotesque in the stories. Game aesthetics, however, were less appealing to many and off-putting to some. This indicates that the learners come with certain preconceptions about game graphics that can negatively impact their engagement if not met. The budget and timescale of the project dictated what was possible for game aesthetics and was a known limitation to the designers. This pilot project aimed at delivering a proof of concept to study the impact of game-based learning methods on adult learners in increasing the learner engagement and learner experience. The findings suggest that gaming can play a positive role in learner engagement. Overall whether the learners liked the games or not, they remembered them, which points towards games supporting improved retention of the concepts and enhanced learner experience.

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ARtales: AR Mobile Application Using Transformative Learning Through Aesthetic Experience – First Evaluation

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Abstract: Nowadays, the noteworthy growth of digital tools for museums and art spaces enhances and redefines the museum experience. The creation of digital applications that provide meaningful experiences in the art space is a real challenge. Transformative learning theories focus on educational processes that aim for the development of critical thinking while some of them involve the aesthetic experience as a medium that can be exploited. ARtales is an augmented reality mobile application for the National Gallery of Athens visitors which utilizes transformative learning methods through aesthetic experience in an attempt to offer a more substantial and innovating experience in the gallery. More specifically, users asked to discover hidden symbols, uncover hidden objects and live AR experiences related to different subjects/scenarios in the outdoor spaces of the gallery or in their personal place, in order to develop their critical thinking and revisit the artworks in a playful and substantial way. The application also uses a points-based reward system in the direction of gamification. This study refers to the first use and evaluation of the ARtales application by a number of postgraduate students in order to draw conclusions related to the development of the critical thinking and the transformation of the views and perceptions of the participants, the assimilation of the offered information as well as the acquaintance with the artworks. For this purpose, questionnaire-based evaluation and free conversation with the participants was carried out as well. According to the results derived, the first use showed positive acceptance and response. Last but not least, the study gives suggestions for future work and exploitation as well as future pilot implementation which is of major importance in order for the ARtales app to become feasible for a widespread use in the near future.

Keywords: Augmented reality, Transformative learning, Aesthetic experience, Mobile learning, Museum experience, Game-based learning

1. Introduction

In recent years, museums and art spaces are increasingly seen as learning environments (Jeffery-Clay, 1998). Furthermore, the use of new technologies and particularly mobile devices in the modern museum has contributed to the redefinition of museum experience by "creating new experiences and enhancing familiar ones in unprecedented ways" (Bradburne, 2008). Especially, Augmented Reality (AR) emerges as an important tool for reshaping digital experiences and "has a significant positive effect on motivation to learn" (Gopalan et al., 2017).

Transformative learning is a theoretical approach of education which has been applied in many different frameworks. "Between 2005 and 2017, fertile ground for research studies about transformative learning and the arts within the field of adult education yielded" (Blackburn Miller, 2020), recognizing the transformative power of art and its contribution to empowering and engaging participants (Bentz, and O'Brien, 2019).

The ARtales app is an AR application for the National Gallery of Athens created as an attempt to combine elements from transformative learning methods with aesthetic experience in a digital tool and provide innovating learning experiences in the gallery, aiming to the development of critical thinking apart from the acquaintance with the artworks. This study concerns the first use and evaluation of the ARtales app by a number of postgraduate students. In this paper, after a brief review of relevant literature and a short description of the ARtales app, the evaluation method and the findings of the whole process are described in detail. Finally, conclusions are documented and suggestions for future exploitation in order for the ARtales app to become feasible for a widespread use in the near future are given as well.

2. Literature review

2.1 Transformative Learning and Aesthetic Experience

Transformative learning is defined as the "process by which we transform problematic frames of reference (mindsets, habits of mind, meaning perspectives) – sets of assumption and expectation – to make them more inclusive, discriminating, open, reflective and emotionally able to change" (Mezirow, 2009). This process "involves learning to think critically by questioning assumptions and expectations that shape and influence the

way we think and do" (Crowther and Sutherland, 2006) which Kegan (2000) refers as "way of knowing". In the process of transformative learning, the concept of "experience" plays a dominant role, according to Dewey (1938), as it "allows a holistic approach to education, in the sense that it is based on the interaction between the human being and the world" (Hohr, 2012). In addition, critical thinking – which Freire (1970) first refers to - is used as "a tool for self-determination and civic engagement" (Giroux, 2010) which leads to critical awareness while dialogue between instructor and learner is also of great importance in the transformational process (Koulaouzides, 2015).

Aesthetic experience, concerns processes related to seeing, perceiving, understanding and appreciating a work of art, as well as the pleasure and satisfaction that accompany these processes (Dewey, 1934), (Vessel et al., 2013). These processes involve a variety of emotional responses and other (often knowledge-based) emotions (Vessel et al., 2013). Furthermore, artworks can "facilitate thinking through the critical observation in a way that allows individuals to approach them in their own way and discover their own meaning and according to thinkers of Palo Alto, this function is due to the fact that contact with artworks is related to the function of the right hemisphere of the brain" (Kokkos, 2010). As follows from the above, art can be a useful tool for the reinforcement of the transformative process (Cranton, 2006), (Raikou and Karalis, 2011). Dewey (1934), Greene (1980) and Gardner (1973) refer to the contribution of aesthetic experience to the development of students' imagination and generally to the learning process.

Aesthetic experience has been utilized in a number of approaches within the framework of transformative learning. Freire was the first who integrated artworks and especially sketches by the Brazilian painter Francisco Brennand in transformative learning process in order to support participants to redefine their views (Freire, 1968). Different types of artworks are used in different approaches, such as artworks of high aesthetic value as well as works of mass culture without emphasizing on their aesthetic value. However, it has been shown that the utilization of artworks of high aesthetic value could enforce critical thinking in a largest degree (Kokkos, 2010). Most of the approaches that utilize aesthetic experience are based on observation of selected artworks, critical questions, and conversation about the examined subject (Figure 1) and such an approach is the methodology "Transformative learning through aesthetic experience" which was developed by Kokkos (2022).

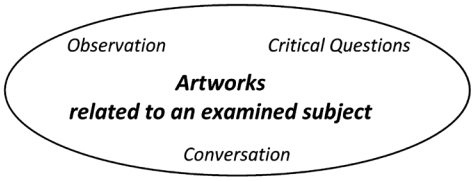


Figure 1: Elements that used in transformative learning methods which utilize aesthetic experience

2.2 Augmented reality

Augmented reality (AR), as a digital technology, enables to "combine real and virtual worlds in real-time, supplementing the real world with computer-generated virtual objects" (Khan et al., 2019) such as text, information, 2D and 3D graphics, sounds and other sensory stimuli. In recent years, the interest in augmented reality (AR) is being increased due to the potential for simulating real-life situations and creating authentic learning tasks (Czerkawski and Berti, 2021). Especially, studies have shown that AR applications can enhance the learning process, learning motivation and effectiveness (Tzima et al., 2019) (Akcayir and Akcayir, 2017). "The increased student motivation may be largely attributed to the elements of curiosity, fantasy, and control presented using AR technology, as student motivation may be directly influenced using an attractive or stimulating medium or learning material" (Khan et al., 2019).

2.3 Museum Learning and Digital Technologies

"Over the past decade, researchers of learning in non-formal educational environments have focused their attention on museums as environments that construct learning experiences and the way visitors learn in them, playing an active role in the learning process" (Filippoupoliti, 2015). "Museums are increasingly asked to demonstrate not only their cultural, but also their educational and social significance and that is why the means to understand how museum visitors learn becomes ever more important" (Hohenstein and Moussouri, 2017). John Dewey recognizes the powerful educational value of museums (G. E. Hein, 2004) while Hein (1998) refers to museum learning as an active process in which knowledge is actively constructed in visitors' minds.

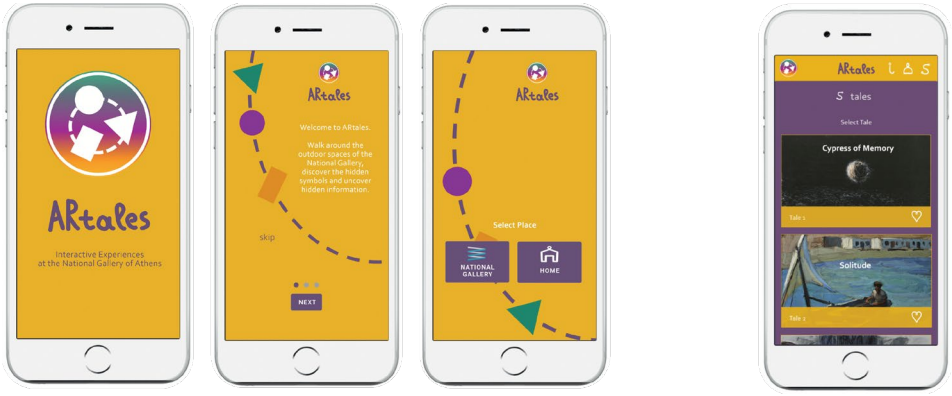
"The use of digital technology in museums and art galleries emerges as a dynamic tool which offers visitors the opportunity to better understand the exhibits and collections that interest them, create their unique personal context to each visit and live a meaningful experience in the museum" (Keene, 1998). Especially, mobile devices enhance the visit and assist visitors on several levels utilizing the advantages of mobile learning (Wessel and Mayr, 2007). Regarding the utilization of digital technology in the modern museum, a great number of digital applications has been developed all over the world. Although these applications provide users with information of high-learning value, they lack to offer opportunities for dialogue between the user and the museum, for participatory learning and for the users to add their own social meaning to the museum experience (Sexton and Lagoudi, 2021).

2.4 The National Gallery of Athens

The National Gallery of Athens in Greece was founded in 1900 and encompasses in its collections more than 20,000 works of painting (National Gallery, 2022a), sculpture, engraving and other forms of art and is the treasury of the latest Greek artistic creation. It also owns a remarkable collection of Western European paintings. The National Gallery of Athens has developed 4 mobile applications which offer access to rich content, information, and audio-visual material (National Gallery, 2022b). Therefore, although they are useful tools, they do not enable users to interact with the artworks in a more creative and immersive way.

3. The ARtales app

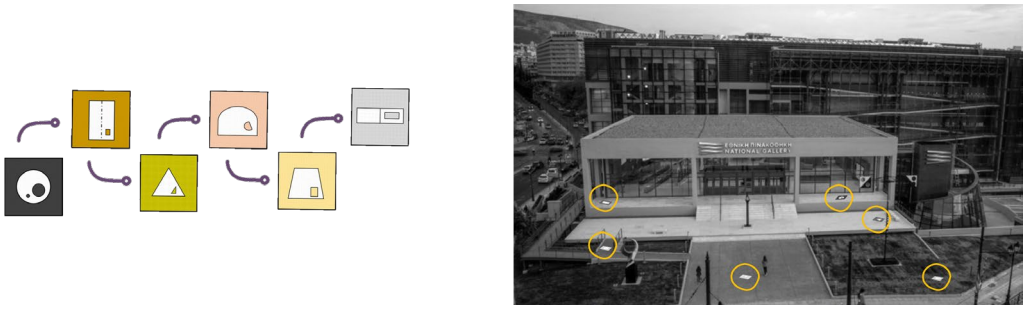
ARtales is an AR mobile application created for the National Gallery of Athens visitors which utilizes transformative learning methods through aesthetic experience (Figure 2(a)). Via the application, visitors can live different AR experiences in the outdoor spaces of the gallery, after their visit to the gallery, while they could use the application at home. Every AR experience is based on a different scenario related to a social or more personal issue such as forest fires, loneliness in everyday life, feelings, memory and lethe (Figure 2(b)). The goal is for the visitors to take part through the application to an original AR experience which will support them to develop their critical thinking and redefine their views about the examined issue beyond the better understanding of the artworks.



(a) (b)

Figure 2: Screens of the ARtales app (a) On boarding/introduction screens (b) Scenario selection

Based on the theories described above (Paragraph 2.1), the AR experiences that are provided incorporate elements from the relevant transformative learning models in conjunction with the interactivity and the possibilities offered by the augmented reality. Especially, every AR experience utilizes a number of paintings from the National Gallery's permanent collection with themes related to the selected issue, which could create a visual scenario that deals with questions related to the sub-topics of the subject matter.



(a) (b)

Figure 3: (a) Map of symbols and (b) their position in the outdoor spaces of the Gallery

During the navigation, users are asked to discover a number of symbols in the outdoor spaces (Figure 3), scan them with the mobile camera and uncover hidden objects each one related to a different artwork and read critical questions about the subject (Figure 4(a)). At the same time, information about the artworks and the examined subject is given in the form of readable text as well as audio material. At the end of the scenario, a summary with important data about the examined subject is provided (Figure 4(b)). The exact same scenarios can also be played by the user at home. In this case, instead of looking for the symbols around, user is called to interact with them through the screen.

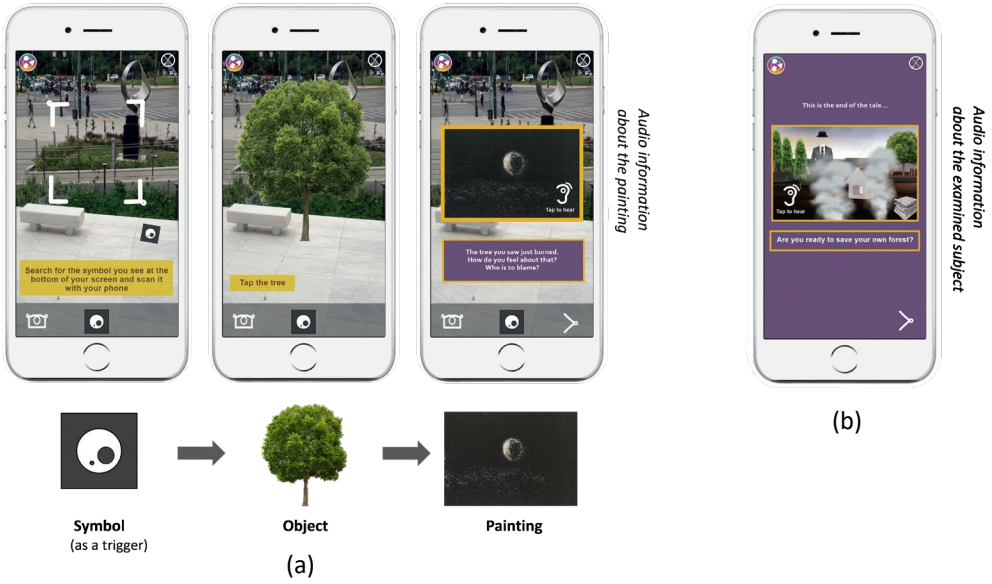


Figure 4: Screens of the AR experience (a) Uncovering a painting (b) Final screen of the scenario

In the direction of gamification, the application uses a points-based system of prizes based on each specific scenario, similarity of the scenarios, the number of scenarios that have been completed and the place (National Gallery or home). The user can obtain more prizes by answering optionally to a number of quizzes while after having collected a certain number of prizes, user is awarded with a real gift such as a book from the National Gallery Shop. The application also provides instruction screens and user profile with user's favourite stories, user's progress as well as awards and badges received.

4. Method

The purpose of this case study was to conduct an initial trial of the application by a small number of users in order to draw conclusions at various levels that will contribute to the future pilot implementation of the ARtales app. Specifically, in this trial users were asked to try out a specific AR scenario. The aim was to investigate the impact of using the application on 3 levels: (1) the contribution of the ARtales app to the assimilation of the information given in relation to the artworks as well as the examined subject, (2) the effectiveness of the utilization of transformative learning elements by examining the development of critical thinking and the transformation of views and perceptions of the participants about the examined topic and (3) the evaluation of the AR experience with respect to the general impression that participants gained. According to the above, a

questionnaire-based evaluation took place using questionnaires of different types before and after the use of the ARtales app by the participants.

4.1 Selected scenario

The scenario selected to be tested by the participants is entitled "Cypress of Memory" (as the title of the painting by Tassos Christakis which is used in this scenario) and concerns the issue of forest fires. The reason for this choice was that forest fires is a worldwide and widely known phenomenon, known to everyone, regardless of cognitive background and interests.

"Forest fires is one of the major environmental disasters that has serious consequences for the ecosystem, services, biodiversity as well as humans" (Wang et al., 2021). "Worldwide, millions of hectares (ha) of forests and other types of vegetation burn every year. Covering nearly one third of the land surface of the globe, forests make a wide range of direct and indirect contributions to human well-being" (Halleux, 2020).

The scenario examines the causes and impacts of forest fires, the reasons that prevent nature from regenerating naturally, reforestation as a restoration practice, ways to prevent forest fires, and volunteering. In particular, the scenario considers the attitude of individuals towards the issue, how conscious they are of the effects of fires in the ecosystem as well as their willingness to help. Six artworks uncovered by the user during the AR navigation are used as a reason to pose questions via the application related to the subtopics mentioned above while information about the artworks - the techniques and the messages - is provided (Table 1). As an example, the information provided for the painting of T. Christakis "Cypress of Memory" is as follows: *"Christakis draws on paper (a wood byproduct) with charcoal – the burnt product of the same material… The solitary burnt-yellow colour intimating fire comes from the actual burning of the paper…"*. At the end of the navigation, a short synopsis with important data about forest fires is given, concluding with a final question which offers motivation for reflection.

Information that provided during the scenario, derived from the WWF (World Wildlife Fund,2022) and National Gallery websites.

Table 1: Symbols, Objects, Paintings and Questions that are used in the AR scenario "Cypress of memory"

Symbol						
Object						
Painting	 *Christakis Tassos* Tree (1947)	 *Bokoros Christos* Cypress of Memory (2002)	 *Tsoclis Kostas* We Are All Responsible (1972)	 *Gaitis Yannis* Composition (1975)	 *Semitekolo Grigoris* Imaginary Landscape (1993)	 *Chouliaras Nikos* The Warm Desert of Life (1996)
Question	The tree you saw just burned. How do you feel about that? Who is to blame?	Why are cypresses important? After a disaster, can they be restored?	How much does forest burning concern us? Although newspapers often report on fire events, we don't care. Why?	We are so focused on our everyday activities that we don't care about the forests. How often do you think of things you can do to protect trees from burning?	Could you live in an area without trees?	Are you ready to live in an unfriendly planet and suffer the consequences of climate change??

4.2 Participants

Participants of the study were 12 postgraduate students (7 men and 5 women) in the field of "Art and Digital Design" of different ages (3 between (20-25), 5 (26-30), 2 (31-40), 2 (>40)) and backgrounds. The criterion of the selection of the participants was their willingness to volunteer, the subject of their studies and easy access to them due to the relevance of the subject of studies and the research interests of the authors. It is noted that the selection of these students due to their familiarity with the subject of digital design was made, taking into account that they could also provide more targeted observations about the design during the discussion, in addition to their contribution to the trial.

4.3 Types of questionnaires

Three types of questionnaires were used for the evaluation which participants were asked to complete, each one of them aimed to examine the impact of the ARtales app in each of the three levels described above. Especially (Table 2), (1) Questionnaire A with 4-point scale questions before and after the accomplishment of the AR scenario, (2) Questionnaire B with closed-type knowledge questions with a unique correct answer and (3) Questionnaire C with the majority of the questions in a 4-point scale, after the AR experience. It is noted that for the evaluation of the development of critical thinking and impact of the AR experience where the aim was to draw qualitative conclusions (trends, assessments) 4-point scale questions were used in the majority of questions.

Table 2: Description of questionnaires that were used for the evaluation

Questionnaires	**Questionnaire A**	**Questionnaire B**	**Questionnaire C**
Examined feature/aspect	development of critical thinking, transformation of views and perceptions	assimilation of the information given in relation to the works of art as well as the examined subject	AR experience with respect to the general impression that participants gained
Types of questions	4-point scale open-ended	knowledge questions with a unique correct answer (multiple choice / matching questions)	4-point scale matching open-ended
Subject of the questions	forest fires, main causes, factors that prevent regeneration, reforestation, actions for the prevention, volunteering	- numerical and geographical data related to forest fires - the artworks, the artistic techniques, the artists, the messages	- user experience and the design of the AR experience - contribution of the AR experience to the understanding of the topic - familiarity with symbols and visual elements
Indicative Questions	"Who is to blame for the forest fires?" , How satisfactory can the burnt area be ¨regenerated¨ by itself? Write 3 factors that prevent ¨regeneration¨, Do you believe that you can help save the forests? Suggest 3 actions.	The highest percentage of burnt areas in Europe are in countries of the (a) Central Europe (b) Mediterranean (c) None of the above, - Which painting do the phrase(s) correspond to? : e.g. (a) The artist uses humorous images to describe an unpleasant reality.	Was the AR experience creative?, Match the symbols with the paintings they uncover, Did the experience help in the assimilation of the information about the works of art?

4.4 Procedure

After visiting the exhibition of the National Gallery's permanent collection, participants were asked to answer questionnaire A and then to use the ARtales app and carry out the AR experience for the selected scenario. At the end of the AR experience, they were asked to answer questionnaire A again and subsequently questionnaires B and C. Finally, free discussion with participants took place. So, the overall procedure conducted, is indicated in Figure 5.

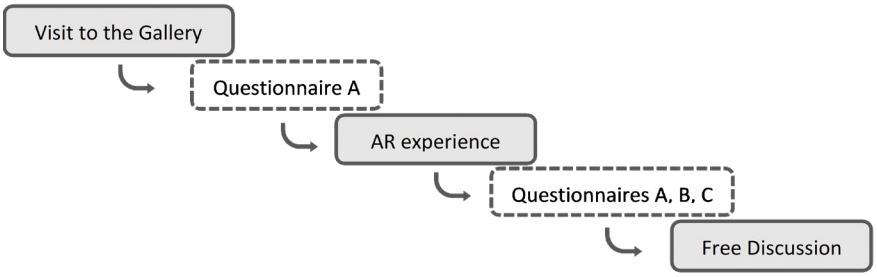


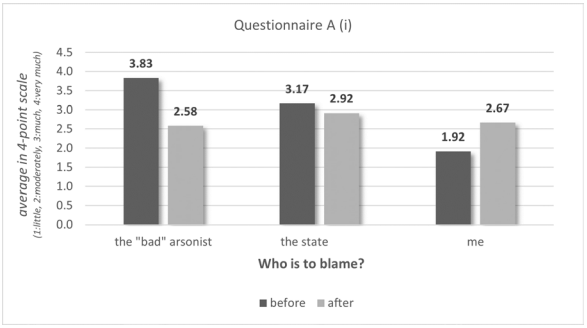
Figure 5: Overall Procedure of the evaluation

5. Findings

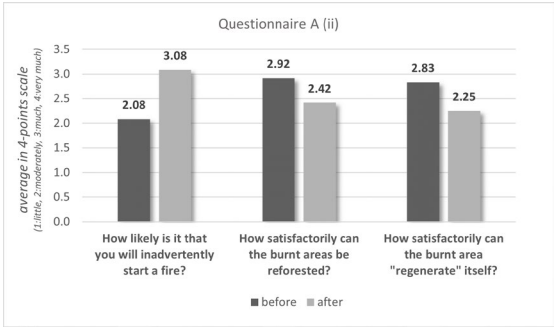
Based on the analysis of the answers of the questionnaires as well as on the discussion which followed, findings were extracted related to the impact of the AR experience in each of the three examined levels.

Concerning the development of critical thinking of the participants (Questionnaire A), the comparison of the answers on questionnaire A, before and after the end of the AR scenario, showed that generally participants differentiated and transformed their views, due to the reflection as well as the processing of information provided to them. Generally, after the procedure the participants gave scores to all questions that corresponded to a higher percentage of reality. Especially, in the question "Who is to blame for the fires?" participants rated 3,83 at the beginning of the course and 2,58 at the end for the bad arsonist (Figure 6(a)) recognizing that a large percentage of fires are due to human negligence and not arson. In the question "How satisfactorily can the burnt

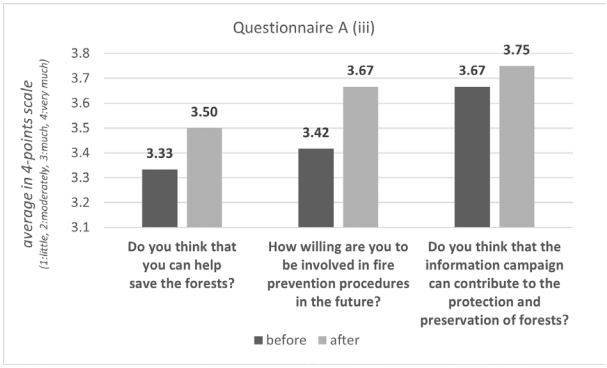
area "regenerate" itself?" participants rated 2,83 at the beginning of the course and 2,25 at the end (Figure 6(b)), realizing that several reasons (such as repeated fires, grazing on burnt land, and erosion) impede nature from being restored naturally. Finally, participants, after the AR experience, were more willing to participate in fire prevention activities in the future, recognizing the value of information campaign (Figure 6(c)), while they were able to write down more targeted actions that could be a step in the right direction and realized that it is not such a difficult process to become volunteers and contribute actively.



(a)



(b)



(c)

Figure 6 (a), (b), (c): Answers on questions about transformation of views of the participants (before and after)

Regarding the assimilation of the provided information, the majority of the participants assimilated, to a large extent, the information related to forest fires as well as to the paintings. In particular, in the questions about forest fires, the majority of the participants answered correctly in each individual question (Figure 7), while 75% of them achieved a score of 100%, answering all the questions correctly (Figure 8(a)). At the same time, in a many-to-one matching question about artworks with 12 matches, 58,3% of the participants achieved a score of 100% and 16,7% answered 11 out of 12 questions correctly (Figure 8(b)).

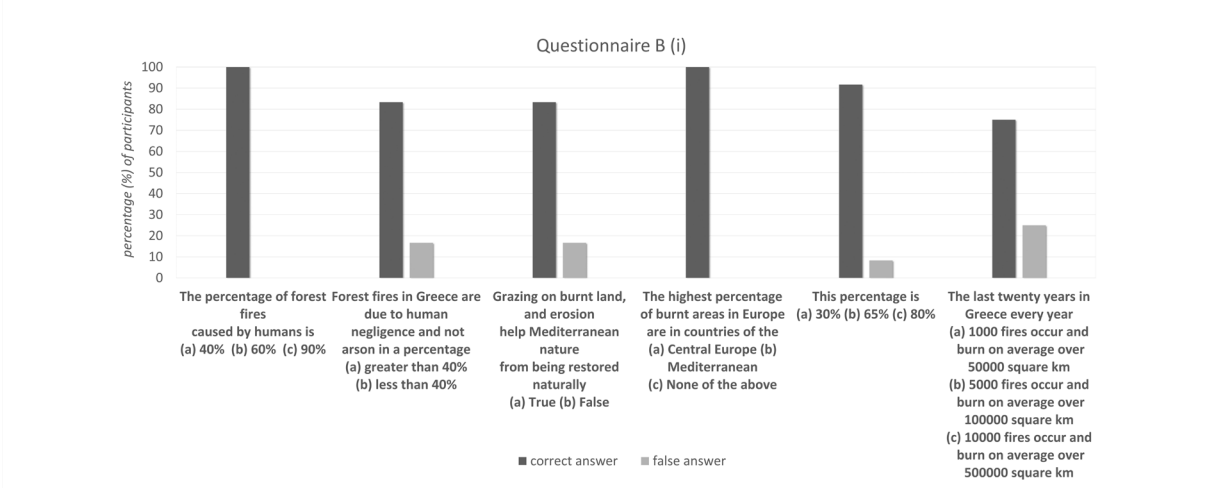
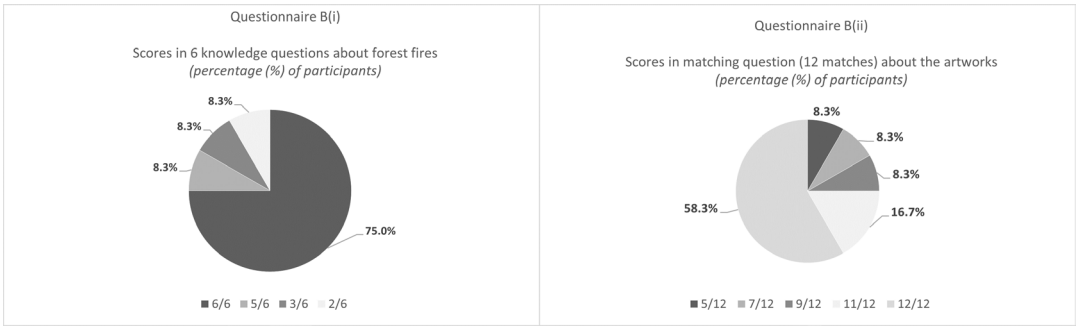


Figure 7 : Answers on knowledge questions about forest fires



(a) (b)

Figure 8: Scores in knowledge questions (a) about forest fires (b) about the artworks

As far as the AR experience is concerned, the participants gained positive impressions and the findings showed that the way that the information was provided by the application through the different points of interest in the outdoor spaces of the gallery, helped them to better acquire the information. Focusing on the results, 81,8% of the participants had the ability to remember the relative artwork connected with a unique symbol (Figure 9) which indicates that the visual relevance of the symbol with the painting it reveals, contributed that the visual information is better imprinted on the mind. 91,7% of the participants characterized the experience as “much” (16,7%) or “very much” (75,0%) easy to use, 100% as “much” or “very much” innovating and 91,7% as “much” or “very much” creative, rating 3 or 4 points in a 4-point scale (Figure 10(a)). Finally, 91,7% of the participants answered that the AR experience helped them (“much” or “very much”) to reflect and redefine their views on the issue of forest fires while 83,4% of the participants stated that the AR experience helped the assimilation of information about the artworks (Figure 10(b)).

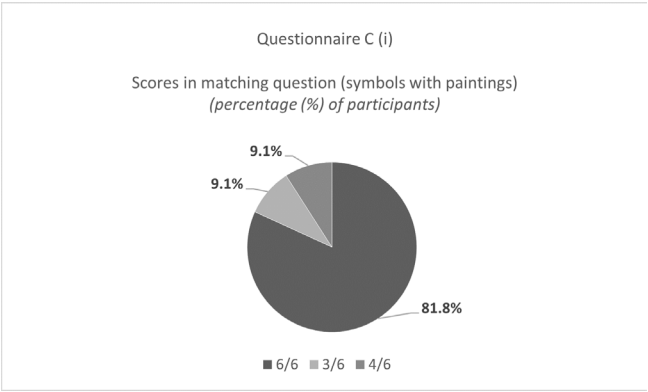
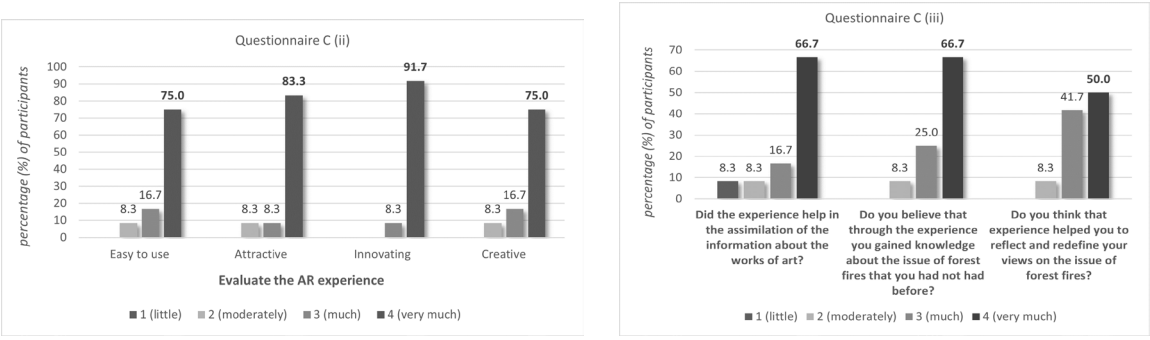


Figure 9: Scores in question of matching the symbols with the paintings



(a) (b)

Figure 10: Answers on questions about the AR experience

Focusing on the free discussion with participants that took place after the completion of the whole process, participants stated that in general the ARtales app “achieved its purpose although it can be improved on some levels”. They also pointed out the importance of the use of augmented reality as “an additionally important incentive in increasing motivation”. In addition, they focused on the content, noting that the information

provided is very clear and precise. They also noted the perspective of the use of the ARtales app in typical education. At the end, they referred to the application as “a beautiful ending of their visit to the gallery” and “a clever way to assimilate the information about the artworks” which also promoted them to “gain a more in-depth view of the examined subject” and stimulated them for “reflection upon experience”. They were also interested in the rewards system which it gave them “an extra stimulus to return to the gallery space and use the app again”, adding that they “would also use the app at home with pleasure, choosing a different scenario”.

6. Conclusions and future work

This study mainly aimed to examine and evaluate the first use of the ARtales application by a number of university students. From the results derived, the first use showed a positive response. Although this survey was conducted on a small – indicative sample and these results could not be generalized, an optimistic perspective for a widespread use and evaluation in the near future emerged. As the participants were art and digital design students, their comments were particularly important as a starting point for further testing and improvement of the application.

The idea of utilizing elements from transformative learning theories in an AR experience, turned out to be an interesting attempt which in this initial trial seemed to achieve its purpose as shown by the data concerning the transformation of the views of the participants. Furthermore, the use of augmented reality as a digital tool with a positive effect on motivation to learn, proved to be equally important. Apart from the efficient assimilation of the information ascertained by the findings, participants also evaluated positively the AR experience in the questionnaires, while in the discussion which followed, they focused on augmented reality as a means for creating an innovating and substantial learning experience in the museum. In addition, since the ARtales app was designed for an art space, the application's contribution to the assimilation of information related to artworks as well as to a better understanding of them was equally important.

A further study could be the pilot implementation of the application in co-operation with adult educators as well as visual artists or art historians in order to draw more targeted conclusions about the efficiency of the application. During this pilot implementation and with the contribution of adult educators, improvements to AR scenarios and to the questions and information that are provided via the application could be implemented. Visual artists would also support the enrichment and improvement of the content related to the artworks which is important to be communicated through the application. Finally, user testing will enable appropriate modifications in the user experience and user interface as well as the further development of the rewards system. Another study could focus on the utilization of the application in Primary and Secondary education, examining possible modifications in the context and the design by taking into account the profile of the students as digital natives.

In conclusion, the project of utilizing transformative learning methods in a digital tool and the proper incorporation of these elements in the design is a real challenge and therefore further study is of major importance. Despite the limitations of this research, undoubtedly the application gives a new dimension to the museum experience. With the appropriate adaptations and improvements, the ARtales app could be used in other museums and art spaces as well, offering more substantial experiences to the contemporary museum, redefining the way we observe, and approach artworks.

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Pre-service Teachers' Player Types and Their Relation to Self-efficacy With Digital Media

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Abstract: Gamification in educational contexts is often used to increase learners' intrinsic motivation and their self-efficacy beliefs, two constructs which are positively related with each other as well as to scholastic outcomes. As self-efficacy beliefs are conceptualized context-specific, it is important to consider various users' needs by adapting the learning environment to their corresponding gamification player types (GPT). Studies show that different GPT are characterized by different motivational aspects (intrinsically motivated, extrinsically motivated, disruptive GTP) Therefore, the aim of the present study is the examination of six different GPT according to the HEXAD typology (Tondello et al., 2016) for pre-service teachers regarding their distribution and their relation to self-efficacy with digital media. Altogether N = 75 pre-service teachers were assessed in terms of their GPT and their self-efficacy with digital media. It was hypothesized that the GPT distribution for pre-service teachers is comparable to the distribution reported by Tondello et al. (2016). Additionally, it was exploratively examined to what extent the different types of players differ in their self-efficacy with digital media. Results show that the GPT distribution in the current sample differs significantly from the expected distribution. Pre-service teachers seem to show specific GPT characteristics due to their profession. Concerning self-efficacy with digital media, pre-service teachers show a high subjective perception of their self-efficacy with digital media, but contrarious to the hypothesis no significant relation was found between GPT and self-efficacy with digital media. The results indicate that pre-service teachers feel confident to the use of digital media in class and that pre-service teachers form a group with a specific distribution of player types and therefore have specific needs in gamified learning environments. Due to the reported high amount of intrinsic player types, game design elements which promote intrinsic motivation should be in the focus of prospective analyses.

Keywords: gamification, player types, self-efficacy, digital media, pre-service teachers

1. Introduction

Current development shows a rapid digitalisation in the school sector, also as a result of the pandemic situation. Using digital media in class is becoming more relevant for teachers, but some feel overwhelmed by those demands because of lacking resources (Weißenfels, Benick and Perels, 2022). To ensure that teachers can meet the requirements of using digital media in class, it is important to promote trust in their own competencies using digital media (self-efficacy with digital media), starting during teacher education. One way of implementing this are digital educational games, i.e. digital games that set clear learning goals and are devised to promote learning (Erhel and Jamet, 2013). Educational games can be very exciting for learners (Dickey, 2011). They are therefore an easy way to enhance intrinsic and extrinsic motivation of pre-service teachers during their university education (Klock et al., 2015) and in a consequence to enhance self-efficacy with digital media as well. Game elements, such as proceeding into higher levels, or the playful environment can enhance extrinsic motivation and help achieve a higher intrinsic motivation (Blohm and Leimeister, 2013). Extrinsic rewards could promote, for example, mastery experiences which fulfil the need for competency and therefore promote intrinsic motivation and foster self-efficacy. Studies show that compared to traditional lesson plans equal learning achievements can be achieved with educational games (Rachels, 2016). To provide an adequate learning environment and to allow for optimal learning, users' needs must be considered. It seems beneficial to look at different player types that are distinguished by differential motivational aspects and interests when it comes to the use of educational games (Marczewski, 2015). For college students, results on the distribution and characteristics of the individual player types are already available (Tondello et. el., 2016), but for the special group of pre-service teachers, player types have not yet been studied in detail. Furthermore, it is still unclear what influence the different player types have on pre-service teachers' self-efficacy with digital media. Therefore, the present study takes a closer look at pre-service teachers' player types and their differences regarding self-efficacy with digital media to derive recommendations for better suited educational games for teachers.

2. Theoretical background

2.1 Gamification

Gamification refers to the "use of game design elements in non-game contexts" (Deterding et al., 2011, p.10). Non-game contexts are for example clinical or occupational as well as educational contexts. Gamification in the context of education is a combination of game components (like points, challenges or stories) and a learning goal (Deterding et al., 2011). Users are supposed to be motivated by the game elements thus attaining higher learning accomplishments (Muntean, 2011). Klock et al. (2015) mentioned multiple game elements for gamification in their work (e.g. narrative, virtual goods, points), which can be used for an effective application of gamified learning environments. When telling a story, for example, users can be immersed by creating a sense of community. Virtual goods can be bought with collected coins and could be used, for example, to buy new clothes for the own avatar which leads to an in-depth personalization. A very important and motivational factor for a lot of users are points and high scores. They contribute to the visualization of achievements and facilitate a comparison with other players which can spur on ambition and intrinsic motivation (Marczewski, 2015). One of the most important fields of application for gamification is in the context of education. Gomez-Carrasco and colleagues (2020) evaluated a gamified training for prospective elementary teachers from Spain. The used game elements used were experience points, classification, rewards, competition and feedback. The training consisted of two sessions per week and used learning videos to convey the theoretical content. Results reveal that most prospective elementary school teachers show positive values regarding their perceived intrinsic motivation, satisfaction, and their learning progress. In addition, a literature review by Hamari, Koivisto and Sarsa (2014) found that gamification mostly leads to an increases in intrinsic motivation and to higher engagement with the learning task and an increased enthusiasm during performance. To enable an increase of intrinsic motivation and more effective learning, it is important to implement a user-centered gamification (Klock et al., 2015) which addresses users' needs. One approach to this could be the consideration of different gamification player types, because they consider players' different types of motivation.

2.2 Gamification player types

Marczewski (2015) developed different player types to categorize users regarding their motivational needs. His model refers to aspects of intrinsic and extrinsic motivation and distinguishes between three player groups: intrinsically motivated, extrinsically motivated, and disruptor player types (see below). Marczewski's (2015) player types have been analysed for reliability and have been validated by Tondello and colleagues (2016) with correlation analyses as well as exploratory and confirmatory factor analyses for college student samples from different countries. It was detected that some player types overlap regarding their underlying motivation which could cause the simultaneous categorization of a player to different player types. Tondello and colleagues (2016) found the following percentages for the individual player types in a student sample: philanthropist (24%), achiever (24%), socializer (19%), free spirit (22%), player (10%), and disruptor (1%). The individual player types will be explained in more detail in the next section.

2.2.1 *Intrinsic player types*

Marczewski (2015) postulates four intrinsically motivated player types which are motivated by their own activities: philanthropist, socialiser, achiever and free spirit. (1) *Philanthropists* are described as players with altruism and the feeling of serving a higher purpose. They interact with and help other players without making demands and want to contribute to society without expecting a reward. (2) *Socialisers* are equally motivated to interact and communicate with other players but here it's more about the social aspect and less about helping others. (3) *Achievers* are motivated by their own performance and competencies. The interaction with other players is less about social connections and more about challenging each other. (4) *Free spirits* prefer to have the freedom to explore the game and develop their own creative ideas (Marczewski, 2015; Tondello et al., 2018).

2.2.2 *Extrinsic player types*

In contrast to intrinsic player types, (5) extrinsically motivated player types are motivated by external stimuli and game elements such as rewards and achievements (Johnson et al., 2016). Extrinsic player types are usually not divided into further subcategories and referred to as players. (Bovermann and Bastiaens, 2020; Tondello et al., 2016; Tondello et al., 2018). Players act comparably to intrinsic player types except for the extrinsic motivation. They are helpful and social, but only if there is a worthwhile benefit for themselves.

2.2.3 *Disruptor player types*

Another category of player types are so called (6) *disruptors*. As the extrinsic player types, disruptors are also usually summarized into a common disruptor type and not viewed individually (Bovermann and Bastiaens, 2020; Tondello et al., 2016; Tondello et al., 2018). The main characteristic of disruptors is the motivation to modify a game. The results can be both positive as well as negative. The game system is either directly or indirectly changed or disrupted by other users. Like the free spirit type, disruptors get motivated by autonomy and creativity. For example, disruptors are looking for gaps or bugs in the system to destroy or improve the game. Even if the disruptor player types only make up a small amount of existing player types (Bateman, Lowenhaupt and Nacke, 2011; Tondello et al., 2018; Trojanek, Fischer and Heinz, 2019), they shouldn't be underestimated. They can influence the game in many ways, by their own actions, their influence on other players or by manipulating the game itself.

The introduced player types could be useful to create adequate digital games for users, in our case pre-service teachers. This would enable adaptive games (e.g., collaborative levels for socialisers or badges for player types), which could improve teacher education because students' needs are considered while learning. As mentioned above, one important variable that influences teachers' use of digital media in the classroom and which should be promoted during their studies, is their self-efficacy with digital media which is further describes in the next section.

2.3 Self-efficacy with digital media

Social cognitive theory describes humans as proactive, self-regulated agents who "influence intentionally [their] functioning and life circumstances" (Bandura, 2006a, p. 164). The core of the theory lies in the interactive triadic reciprocity between personal factors, the environment, and the executed actions (Bandura, 1989). Among the personal factors, Bandura assumes that "people's beliefs about their capabilities to exercise control over events that affect their lives" (Bandura, 1989, p. 1175) are central, naming those beliefs "perceived self-efficacy." For Bandura (1977), self-efficacy beliefs determine behavior directly as well as indirectly through cognitive (e.g., elaboration), motivational (e.g., effort), and affective (e.g., stress), and processes. People with adequate self-efficacy beliefs sets more challenging goals, persevere longer in difficult tasks, and is more resilient (Bandura, 2006b).

In the context of teaching, self-efficacy has been investigated and empirically validated in students (e.g., Joët, Usher and Bressoux, 2011) as well as in teachers (e.g., Usher and Pajares, 2009) and it was mainly confirmed that mastery experiences play the major role in the formation of self-efficacy beliefs (Pfitzner-Eden, 2016). Once established, Bandura (1977) assumes that self-efficacy beliefs for a specific context should be relatively stable which has been empirically validated for teacher self-efficacy several times (e.g., Künsting, Neuber and Lipowsky, 2016). Regarding school closures due to the COVID-pandemic, teacher self-efficacy with digital media played a central role, especially considering that the use of digital media has been shown to be predicted by the specific self-efficacy (Lee and Lee, 2014). Teacher self-efficacy with digital media therefore means that teachers feel confident they can effectively use digital media in class and overcome its technical difficulties and challenges. Moreover, teacher self-efficacy with digital media is closely related to teachers' competence about actually using digital media (Abbitt, 2011).

As different gamification elements can affect specific motivation types by offering external (e.g. points) or intrinsic incentives (e.g. emotional engagement through narrative; Ryan and Rigby, 2020) and therefore foster self-efficacy through mastery experiences, the interesting question arises whether persons with different demands on a game experience have a different development of self-efficacy with digital media. This leads to the aim of the study to analyze different player types and their relationship with self-efficacy with digital media.

2.4 Research question and hypotheses

The following study examines (RQ1) whether the distribution of player types reported by Tondello and colleagues (2016) is replicable in a sample of pre-service teachers. In the present study we assume that the philanthropist player type appears more frequently than other player types (H1.1) whereas the disruptor player type is the least common (H1.2). Moreover, the distribution of player types does not significantly differ from the sample of Tondello and colleagues (2016) in terms of frequency (H1.3).

In addition, it will be (RQ2) exploratively examined to what extent the different types of players differ in their self-efficacy with digital media.

3. Method

3.1 Sample and procedure

Data of *n* = 75 voluntarily participating pre-service teachers (*n* = 66 female) was collected at a German university. They were 23.95 years old on average (*SD* = 4.17, range = 22-44 years) and in semester 7 of their studies (*SD* = 2.19, range = 1-14), but only 69 of them disclosed latter information. The anonymous survey was carried out at the beginning of the summer term 2020 in an online lecture at a German university. The presentation of the items was randomized, and participation was unpaid and voluntary.

3.2 Measurement instruments

3.2.1 Gamification User Types Hexad scale

The „Gamification User Types Hexad Scale" measures the expression of player types on a scale from 1 = "Not true at all" to 7 = "Exactly true". The subscales distinguish between player, philanthropist, achiever, socialiser, free spirit, as well as disruptor. Each player type is measured with four items each, the entire scale therefore consists of 24 items (e.g., "I like mastering difficult tasks"). The scale was translated into German. Tondello and colleagues (2018) conducted three studies to validate the English and Spanish version and found acceptable reliabilities (Cronbach's alpha) of α =.70 for the philanthropist, α =.71 for the achiever, α =.79 for the socialiser, α =.60 for the free spirit, α =.75 for the player, and α =.70 for the disruptor. In the present study, reliability is α =.73 for the philanthropist, α =.77 for the achiever, α =.91 for the socialiser, α =.38 for the free spirit, α =.56 for the player, and α =.66 for the disruptor. As in Tondello and colleagues (2018), the reliability for the player type of free spirit is the lowest.

3.2.2 Self- efficacy with digital media

The scale used to measure self-efficacy with digital media comprised five adapted items from Lin and colleagues (2015; e.g., "I feel secure using basic functions of digital media") and two items from Hung (2016; e.g., "I confidently answer questions in online discussions"). A 5-point Likert scale was used, where a 5 means high and 1 means low self-efficacy with digital media. The reliability of the scale is α =.81.

3.3 Statistical analyses

Analyses were conducted using IMB SPSS Statistics 25 and the statistical threshold of α = .05 was used. To categorize participants into different player types, the highest value of each participant for the different player type was taken into consideration. To do that, a sum value for each participant for the six subscales was calculated. This method is based on the study on player types by Trojanek and colleagues (2019). It is possible that students are assigned to multiple player types at the same time if they have equally high values for different player types. We identified *N* = 101 expressions of player types in our sample with *n* = 75 due to multiple classification of participants to different player types. The N = 101 player types were considered independently in all analyses.

To test hypothesis 1.3, a one-dimensional Chi-Square test (Goodness of fit test) was calculated, to compare the observed distribution of the six player types with the expected distribution of Tondello and colleagues (2016). We transferred the percentages of their sample for our sample of *N* = 101 player types.

A one-sample t-test and a one-factor ANOVA are used to exploratively examine the extent to which the player types differ in their means for self-efficacy with digital media. In the case of calculating the differences in self-efficacy with digital media regarding the player types, the four intrinsic player types are summarised. The effect sizes of the one-factor ANOVA for the explorative investigations of self-efficacy with digital media are given as partial eta squared (η_p^2).

4. Results

4.1 Frequency of player types

Based on the frequencies of each player type in the present sample (*N* = 101) hypothesis 1.1 und 1.2 could be confirmed. The philanthropist was the most common player type (*n* = 54) while the disruptor was the least common with *n* = 1 (see figure 1).

When assigning test subjects to player types, a distinction was made between pure and mixed forms. In our sample (N = 75) n = 18 participants showed characteristics of more than one player type, while n = 57 participants classified as pure forms. Among the mixed forms, n = 8 subjects showed three different player types. The philanthropist was also the most common player type among mixed form subjects.

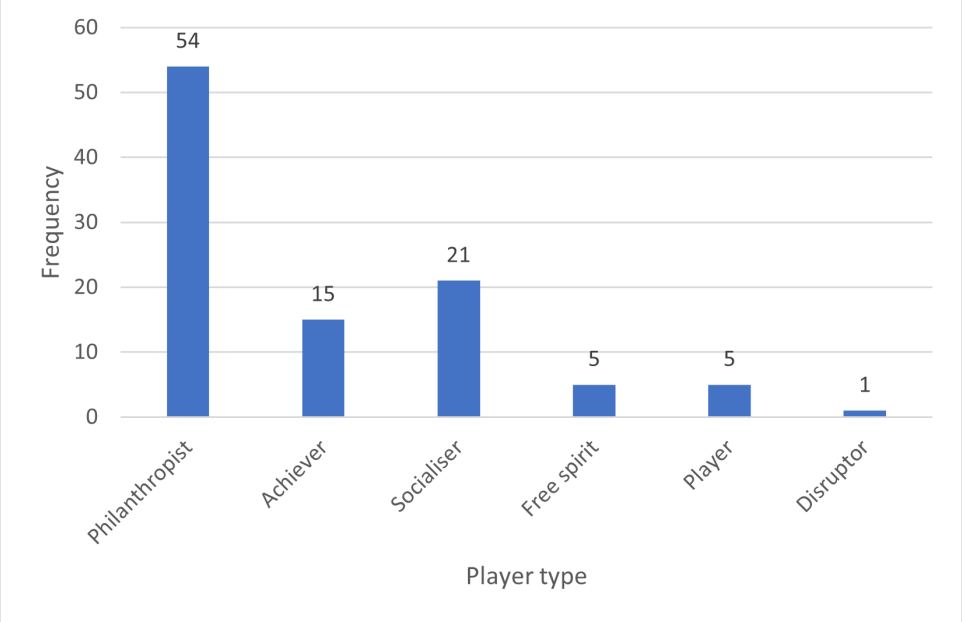


Figure 1: Frequencies of player types including all mixed forms

4.2 Distribution of player types

Referring to H1.3,the Chi-Square test showed a significant difference between observed and expected frequencies ($\chi^2(1,101) = 56.15$, $p > .001$) in comparison to Tondello and colleagues (2016). The present sample contains significantly more philanthropists and significantly less achievers, free spirits, and players than expected (see table 1). Hypothesis 1.3 was therefore rejected.

Table 1: Comparison between observed and expected frequencies of player types including mixed forms

	observed	expected (Tondello et al., 2016)
Philanthropist	54	24,24
Achiever	15	24,24
Socialiser	21	19,19
Free Spirit	5	22,22
Player	5	10,1
Disruptor	1	1,01

4.3 Self-efficacy with digital media

To test RQ2, a median of 3 for the test instrument and a one-sample t-test was calculated. The average self-efficacy with digital media (M= 3.71, SD = 0.70) was higher than the median of 3 ($t(100) = 10.23$, p <.001), why a high self-efficacy with digital media can be assumed in the present sample. A one-way ANOVA revealed no significant difference between the player types regarding their self-efficacy with digital media ($F(5,95) = 2.01$, p = .085, η^2_p = 0.10). Furthermore, there were no significant differences regarding self-efficacy with digital media between intrinsic, extrinsic and disruptor player types ($F(1,98) = 1.38$, p = .257, $\eta^2_p = 0.03$, see table2).

Table 2: Descriptive statistics for self-efficacy with digital media

	Mean	*SD*
Philanthropist	3.56	0.70
Achiever	4.07	0.60
Socialiser	3.67	0.71
Free Spirit	3.94	0.72
Player	4.20	0.58

	Mean	*SD*
Disruptor	3.43	.
Intrinsic player types	3.69	0.70
Extrinsic player types	4.20	0.58
Disruptor player types	3.43	.

5. Discussion

The goal of the present study was to take a closer look at the player types according to Marczewski (2015) in a sample of pre-service teachers regarding their frequencies and their differences in self-efficacy with digital media.

5.1 Comparability of pre-service teachers' player type distribution with prior findings

Hypotheses 1.1 and 1.2 could be confirmed as philanthropist was the most common and disruptor the least common player type. This finding matches the results of the study by Trojanek, Fischer and Heinz (2019). In addition, the philanthropist player type also shows characteristics, e.g. helpfulness and interaction, which could be transferred to personality traits of a teacher, e.g., openness to interactions with students (Kim, Jörg and Klassen, 2019). In the study by Tondello et al. (2016), the player type philanthropist correlated with extraversion, conscientiousness, and neuroticism. Likewise, the philantropists' altruistic actions during a game match the behaviour of a teacher towards pupils that is desirable and promotes the intention to share knowledge (Chen, Fan and Tsai, 2014). The philanthropist's matching characteristics with teacher personality could be an explanation for the high amount of this player type in the current sample.

Disruptor player types are least common among student teachers. As confirmed in multiple studies (Bovermann and Bastiaens, 2020; Tondello et al., 2018) the disruptor player type is also the least common in the general population. In addition, the description of the disruptor as a destroyer and blaster of boundaries does not fit the characteristics of a teacher, as they should be a role model for students.

Regarding the distribution of player types, hypothesis 1.3 could not be confirmed. The observed distribution does not correspond to the expected distribution from literature (Tondello et al., 2016) as the present study examined a special population instead of the general college student population.

5.2 Relation of player types and self-efficacy with digital media

The surveyed sample shows a high self-efficacy with digital media. One reason could be the age of the participants. Compared to working teachers the present sample is younger in age. Teachers with less working years show a higher self-efficacy with digital media (Hung, Huang and Hwang, 2014). Compeau and Higgins (1995) can confirm that a high self-efficacy goes hand in hand with a higher digital media usage. Because of their high self-efficacy, pre-service teachers are more likely to use a digital approach during a lesson than older teachers with a lower self-efficacy with digital media. There were no differences found in self-efficacy with digital media between the different player types. The reason could be that all participants undergo mastery experiences. The study by Li and colleagues (2017) found a positive relationship between computer self- efficacy and intrinsic motivation. However, no difference between intrinsic, extrinsic and disruptor player types can be found in the sample studied. This may be due to the generally high self-efficacy with digital media of the surveyed sample. In addition, the sample comprises only six persons with a non-intrinsic player type, which makes it difficult to compare the groups.

5.3 Limitations

One problem of the present study is the sample size of $N = 75$, which lowers the probability of finding an effect in the present sample. Likewise, the observed sample only consists of pre-service teachers from one German university. Therefore, it is not possible to draw general conclusions about pre-service teachers in other countries.

Furthermore, the player type distribution in the current sample cannot be seen as generally representative for college students, because of the discrepancy between the expected and observed player type distribution. However, first indications arise for the group of pre-service teachers specifically. The existence of only one disruptor type is problematic for statistical calculations. Additionally, the disruptor player type also belongs to a participant with a mixed form. It is therefore difficult to make reliable statements about the distribution of player types.

Due to the classification into mixed forms, the interpretation of the results is complicated. Furthermore, the player and disruptor subtypes are not considered in a more differentiated way in the instrument used. The different group sizes pose a problem especially when calculating the ANOVA for the exploratory analysis of self-efficacy with digital media. In terms of reliability, there is a discrepancy between the literature (α = .60) and the sample studied for the free spirit player type (α = 0.38). Especially the reliability in the considered sample can be estimated as low regarding the free spirit and can represent a further problem of the study. Prior experiences and competencies of the pre-service teachers in dealing with digital media were not assessed and could also influence results, as experiences with digital media and attitudes towards e-learning, for example, may have an influence on self-efficacy with digital media.

5.4 Implications and future research

Regarding the results of the present study, the different player types have no effect on self-efficacy with digital media. Future studies should take the aspects mentioned into account and the reported results should be verified with a larger sample. As many participants were intrinsic player types, the results can only be interpreted for this group. Comparing intrinsic player types with extrinsic and disruptor player types provides material for future research. Nevertheless, a high level of self-efficacy with digital media was demonstrated among the pre-service teachers tested in the present sample. To make educational games appealing to every type of player, further research should be conducted (e.g., the relation of player types and personality traits) to enable individualization in teacher training and a suitable educational offer.

Based on the present findings, pre-service teachers seem intrinsically motivated and preferably belong to the philanthropist player type. Therefore, the aspect of intrinsic game elements should be in the foreground for the use of learning games for pre-service teachers. Above all, communication and social interaction are important to them. This can increase the players' motivation and is reflected in their choice of profession.

Acknowledgements

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SynErGame – Gamified Knowledge Building on Synchronizing Energy Supply and Energy Demand

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Abstract: Climate change is one of humanity's biggest challenges. With reference to power grids, there is a strong need for decarbonization alongside for a substantial increase in renewable energy generation. Keeping in mind that renewable energy sources are volatile – solar and wind power are heavily weather dependent – it is necessary to ensure the balance between power generation and power demand in the European power grid at all times. Significant deviations in grid frequency or bottlenecks could lead to a blackout. This raises the need for flexibility in the power grid substantially. An option so far relatively little explored is to make use of industrial demand-side flexibility. With a share in the power demand of about 45 per cent in Germany, industry could contribute significantly to power grid stability. While technologies for industrial demand-side flexibility have been comprehensively explored by the scientific community and (prototypically) implemented in industry, this knowledge has not spread to a broader audience. To foster knowledge on industrial demand-side flexibilization, we developed an approach using a serious game called SynErGame, synchronizing energy supply and demand. Within two game modes, one perspective macro-oriented and the other industry-oriented, a player learns about the benefits and challenges of using demand-side flexibility options to stabilize a power grid. The paper first introduces the topic of flexibilizing industrial power demand. Secondly, requirements are derived and the game design is outlined in detail. Thirdly, the paper shows how to make the game accessible via browser or app on mobile devices, such as smartphones and tablets. During ongoing use, SynErGame has proven particularly effective for audiences inclined to digital technologies, such as students.

Keywords: Climate Change; Demand-Side Flexibility; Serious Game

1. Motivation

Climate change is one of humanity's biggest challenges. Among the main contributors to climate change are greenhouse gases emitted by burning fossil fuels such as coal, crude oil and gas (European Commission, 2022). In 2015, approximately 190 states signed the United Nations Framework Convention on Climate Change agreement in Paris to meet the challenge of global warming. The long-term agreement goal is to limit global warming below 2°C as compared to pre-industrial values to reduce the risks and consequences of climate change (United Nations, 2015). Consequently, the European Union (EU) derived and updated its energy and climate targets, aiming at least for a reduction of 55% of greenhouse gas emissions compared to 1990, at least a 32% share increase in renewable energy generation and at least a 32.5% improvement in energy efficiency (European Commission, 2014). Member states in the EU still seek to increase these ambitious targets. For instance, by the Climate Protection Plan 2050 and even more by the new Federal Climate Change Act amended in 2021, Germany set the goal to achieve greenhouse gas neutrality by 2045 and foster renewable energy integration for electricity among others (Federal Ministry for the Environment, 2016; Federal Ministry of Justice, 2021). The associated transformation of the energy system into a secure, fair, and sustainable system to meet these targets faces several challenges (Gunningham, 2013). They are reflected in the target triangle of security of supply, energy justice, and environmental sustainability (Bauer et al., 2021). The challenge increases with global primary energy consumption continuing to rise and the need to cover economy and population energy demand at affordable prices. The war in Ukraine very clearly points out this dilemma and underlines the need for a rapid switch to renewable energy sources (Tollefson, 2022).

The integration of renewable energy sources such as wind and solar contributes to higher fluctuations in energy supply, specifically in the power grid. A power grid requires a constant balance between power supply and demand monitored by its frequency (Haes Alhelou et al., 2019; Papaefthymiou et al., 2018). Failing to balance supply and demand provokes deviations in the power grid's frequency beyond its nominal operation limits, as experienced in severe incidents e.g., in 2018 and 2021 within Europe. In 2018, the frequency deviation caused by power deviations in the control area of Serbia induced in EU a six-minute delay in electric clocks, steered by the grid power frequency (ENTSO-E, 2018). In 2021, a higher flow than expected caused an overload in Croatia, resulting in the busbar tripping and, consequently, the split of the continental synchronous area in Europe into two parts (ENTSO-E, 2021). If these frequency deviations had become even greater, the power grid would have threatened to collapse in a so-called blackout with possibly far reaching consequences (Eckert and Eberlein, 2020; Haes Alhelou et al., 2019). These consequences include massive restrictions for all areas of daily life, such as food supplies, health system, and communications infrastructure (Petermann et al., 2011). Hence, flexible demand by modifying the demand pattern based on input signals arises as a complement to traditional solutions. This is meant to mitigate supply and demand fluctuations and is contributing to a stable and reliable power supply (Roesch et al., 2019). Demand Response (DR), a method to synchronize power supply and demand by adjusting power demand, can thus contribute to power grid stability (Murthy Balijepalli et al., 2011; Siano, 2014). Industrial consumers offer substantial potential to contribute to flexible demand, since they account for 25.6% in the EU's and 25.1% in Germany's total final energy consumption as well as 44.7% of Germany's power consumption in 2019 (eurostat, 2022; International Energy Agency, 2022).

Although the concept of DR is key to energy transition and therefore has been intensively explored by the scientific community and implemented (prototypically) in industry, the concept is still little known to the public. To foster knowledge on the topic, we developed an approach using a serious game called SynErGame – synchronizing energy supply and demand. In section 2 of this work, the approach and the design of SynErGame are outlined, followed by its implementation in section 3. Section 4 describes the application of SynErGame. Section 5 summarizes the work and gives an outlook on future research.

2. Game Design

To simultaneously facilitate learning and increase the motivation of learners, game-based approaches are suitable. So-called educational games or serious games, for example, show clear signs of typical game design elements and allow for entertaining mentor amusement while also supporting learners in improving skills or understanding new subjects (Abele et al., 2017). Empirical studies have shown that game-based learning approaches achieve higher learning outcomes than the comparatively passive conventional method of frontal teaching (Pivec and Dziabenko, 2004; Prensky, 2003).

Game-based learning approaches are well known and commonly used in manufacturing, especially with lean manufacturing and digitalized manufacturing (Teichmann et al., 2020; Yesilyurt et al., 2019). Regarding the energy sector, there are games on policy issues (Suzuki et al., 2021), renewable energy generation (Ouariachi et al., 2019), and power grid operation (TenneT, 2020). However, these games focus on power supply, while power demand is only considered to a small extent. Therefore, a game-based learning approach is needed focusing on the power demand fostering knowledge on industrial DR.

SynErGame has been developed using an iterative approach inspired by the information system research framework with its inherent cycles (Hevner, 2007). Therefore, developers have worked together closely with domain experts to incorporate their knowledge and experience into the game design next to findings from relevant literature on industrial DR. The first step defines the requirements for the game that were further refined in the course of development. In the second step, during actual development of the game's approach and design, semi-structured interviews of domain experts were regularly conducted, processed, and the results integrated into the further development.

2.1 Requirements

The overall target of the game is to foster knowledge on how industrial DR can support the transition to renewable energies as well as the associated challenges. To this end, entry barriers need to be low to appeal to a broad target group. Therefore, the game must be comprehensible without a technical background and without time-consuming preparation. Implementation as a highly platform-independent electronic game allows it to be run on a variety of different devices. In terms of content, the game needs to simplify and illustrate the complex processes and how they interdepend in the power grid and in companies offering DR potential. The game,

therefore, aims at the fundamental background, principles, and goals of industrial DR. Players can become familiar with possible changes, effects, challenges, as well as advantages in an appealing manner. By playing an active role in the game, each player learns about the implications and consequences of specific actions at both grid and company level.

2.2 Structure and Gameplay

The processes of industrial DR are well described in literature (Papaefthymiou et al., 2018; Roesch et al., 2019; Sauer et al., 2019). However, for a broad audience with a non-technical background, they are way to complex and need to be simplified to make them easy to experience. Therefore, SynErGame is organized in three modules. The introductory module explains the fundamental background, principles, and goals of industrial DR. The explanation is text-based and supported by optional deep-dive videos. To address both technically proficient and non-proficient players alike, the introductory module can be skipped quickly. The two game modules differ in their focal point. The first module focuses on a power grid level with the player being responsible for the power grid's stability in a fictional city. The second module gives the player the responsibility of an entrepreneur to enable economic manufacturing despite fluctuating energy costs. The two modules also represent two different game modes the player can choose from (see Figure 1). Since the basics of industrial DR have been explained in the introductory module, the focus at the beginning of the game modes can shift to a tutorial on how to play the specific game mode. This way, the elements of the game mode are explained, and the player is set up to experience the game.

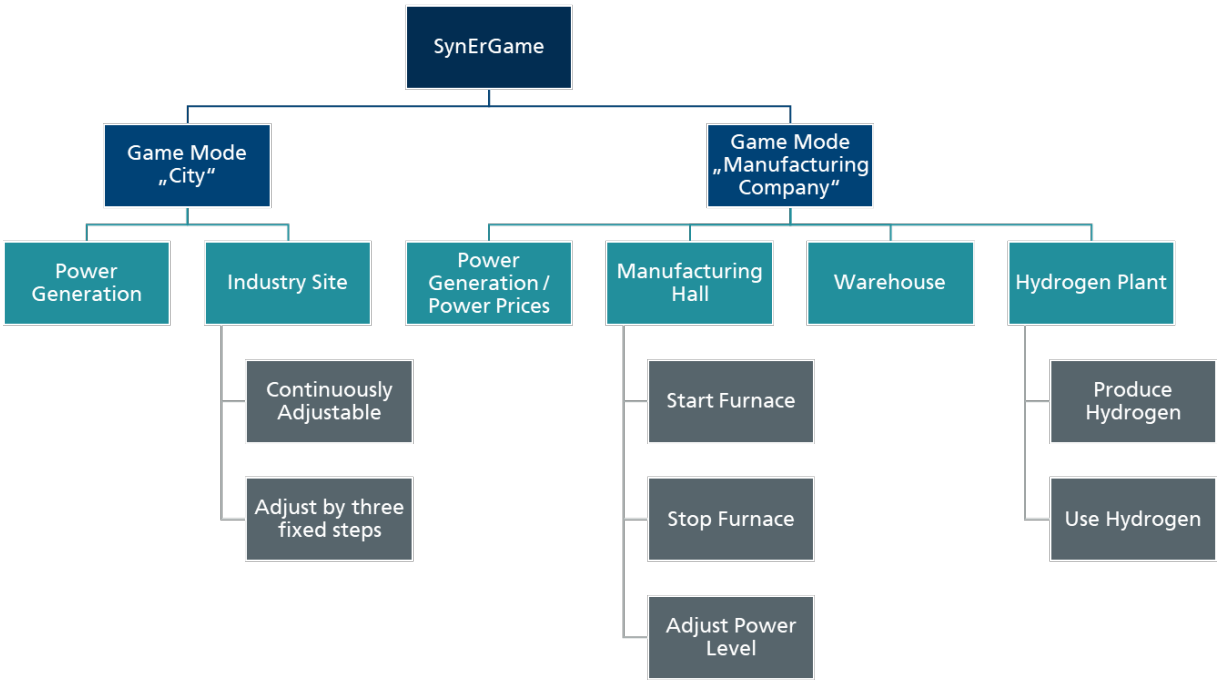


Figure 1: Structure of SynErGame including two game modes and respective elements and actions

2.2.1 Game Mode "City"

The aim of the game mode "city" is to show how industrial DR can contribute to stabilizing the power grid. For this purpose, a fictional city is designed comprising infrastructure, housing, and industry - the power consumers. Furthermore, there is power generation from renewable energies, i.e., wind turbines and solar panels. The gameplay is round-based. At the end of each round, a balance of power generation and power demand is calculated. If these match, the frequency remains the same while the power grid is in balance. The player receives points for this achievement. If power generation and power demand deviate from each other, the frequency of the power grid changes and the player receives penalty points. If the deviations are too significant, the power grid collapses, a blackout occurs, and the game is over. After a selectable number of rounds, the game ends regularly, and the player scores depending on the points won or lost for the power grid's frequency state at the end of each round. Therefore, it is of great importance for the player to observe the grid frequency displayed at any time, as well as the current power generation and power demand.

Being dependent on the weather, the power generation of the wind turbines and solar panels cannot be controlled by the player. However, weather forecasts enable the player to decide whether power demand must decrease or increase in the following round. By decreasing and increasing power demand with industrial DR measures, the player can influence the power grid's frequency. To do so, two industrial DR measures according to VDI (2020) have been implemented and can be triggered by the player using industry sites in the city. One industrial DR measure is continuously adjustable, though affecting the following round. For example, if power demand is increased in the current round, it cannot be further increased in the subsequent round. The second industrial DR measure goes without such dependencies on subsequent rounds but can only be adjusted in three fixed steps. The difficulty for the player is to balance power generation (with its prediction via weather forecast) and power demand (taking into account the characteristics of the different industrial DR measures) at all times. At the same time, this allows the player to experience how industrial DR, even specific measures, affects the frequency of the power grid.

2.2.2 Game Mode "Manufacturing Company"

The game mode "manufacturing company" aims to show how industrial DR challenges or benefits a manufacturing company's site. It is modelled on a fictional company, manufacturing silicon wafers for semiconductors. As the manufacturing process is very energy-intensive, it is important to maintain the company's competitiveness by using the cheapest possible power in the face of volatile power prices resulting from volatile power generation by renewable energy sources. The gameplay is continuous, and the player tries to use power as cheap as possible to manufacture wafers. The quantity of wafers to be produced in a given period is predefined, and so is turnover. The player may influence the costs at which power is purchased for manufacturing the wafers. Accordingly, the company's profit increases or decreases in inverse proportion to the cost of power. The game is lost when the company's assets are depleted, or its inventory of saleable wafers drops to zero. The game is won if sufficient profit is generated to be able to implement four expansions of the company. The two central tools of the player are, therefore, a graph showing the current power demand of the company and the power price forecast for a certain period into the future, as well as extensive statistics on the company's performance.

At the beginning of the game, the company consists of a manufacturing hall with four melting furnaces, a warehouse with limited capacity, and a hydrogen plant:

- Manufacturing hall: The manufacturing hall comprises four melting furnaces for the actual wafer manufacturing process. Each melting furnace can be switched on or off discretely. The power consumption profile of the furnace is known to the player and can be compared with the expected power prices in this period.
- Warehouse: After being manufactured, wafers are stored in the warehouse. From there, they are sold automatically. So the player can only control the inflow to the warehouse. The outflow happens automatically. It is important that the stock level does not drop to zero. At the same time, if the stock is full, no more wafers can be manufactured. So, if the stock is full, cheap power cannot be exploited.
- Hydrogen Plant: The hydrogen plant allows for producing hydrogen by means of electrolysis - which requires a lot of power. In turn, power can be generated from the hydrogen via fuel cells. This creates a storage possibility that allows the player to use more power when it is cheap and less power when it is expensive.

If the cost-effective wafer manufacturing has generated sufficient profit, five company expansions can be implemented:

- Power controller: With a power controller, the melting furnaces in the manufacturing halls can not only be switched on and off but also operated on five power levels. Although this does not change the total power required to manufacture the wafers, it can change their timing by adapting power consumption profiles.
- Warehouse expansion: An expansion of the warehouse allows for storing more wafers.
- Hydrogen plant expansion: An expansion of the hydrogen plant will allow a larger amount of power to be stored in the form of hydrogen.
- Building a manufacturing hall: By building an additional manufacturing hall, the company's capacity for wafer manufacturing can be expanded by four additional melting furnaces.
- Building a hydrogen plant: By building an expensive additional hydrogen plant, the capacity of the company to synthesize and use hydrogen for their power supply can be extensively expanded.

The difficulty for the player is to maintain the necessary wafer manufacturing at all times while achieving competitive costs by sourcing power as cheaply as possible. The interrelationships within the company are complex and characterized by a wide range of possible actions. At the same time, this allows the player to experience the impact of the use of industrial DR in a manufacturing site.

2.3 Findings for Players

Since the primary purpose of SynErGame is to foster knowledge on industrial DR among a broad audience, gaining experiences and findings is most important for the players. Therefore, an essential part of both game modes is to explain why the game was won or lost. In the game mode "city", this is explained using the power grid frequency; in the game mode "manufacturing company", it is explained using the statistics and how power costs affect the profitability of companies. Players can use this information to understand the consequences of their actions and how to act better next time.

3. Implementation

SynErGame was implemented as an iterative process and in close cooperation between developers and domain experts. In the first phase, domain experts and developers had to decide which scenes and industries to include in the game and what to allow the players to do. As outlined in section 2.1 for the game mode "city", it was chosen to depict a whole city with several different companies. This was meant to give players an overview of the topic of industrial DR and the general challenges it brings without the limitation of only looking at one specific industry or manufacturing process. This context had to be combined with the usual approaches and rules of games, for example, regarding navigation and control. Despite the complexity of the topic to be transported, the game should be simple, easy to learn and understand, especially regarding controls. With the serious and real-life message behind it, the target groups of the game differ from casual or entertainment games. Therefore, entry barriers to step into the game should be as low as possible. The game mode "manufacturing company" was created to allow players a closer look at the specific challenges a modern manufacturing company with its individual manufacturing process steps faces with industrial DR (see section 2.2). However, the same challenges regarding game and graphics design had to be dealt with when creating this game mode. The input possibilities and controls, especially when developing applications for mobile devices with touch input, needed to be considered for every step of design and development. There are restrictions and limitations regarding touch input, especially on small displays of mobile devices, while the game has to make sure that all necessary control elements (like menus, arrows, or other actions) are displayed at all time without taking too much space. Thus, creating and adjusting user interfaces for different aspect ratios (e.g., browser vs. smartphone) was one of the biggest challenges for game and graphics design during development.

The fundamentals of the graphic design were created to generate a friendly and inviting environment. For the game mode "city" for example, bright and appealing colors were chosen, and the city is depicted with a river and sunshine. For both game modes, we included as many graphical details as possible to aim for a realistic and appealing look. The game mode "manufacturing company" also had the aspiration of a modern appearance, in look as well as in content, being another reason why a company for manufacturing wafers for the semiconductor industry was chosen.

For actually implementing SynErGame, we used two main tools: Blender (blender, 2022) to create graphics assets and Godot (godot, 2022) as a game engine for bringing all components together, and building and extracting a functioning game. Godot is a lightweight game engine suitable for developing browser games, but its framework also allows for creating apps for mobile devices, which, for example, influences the final download size of the game. The technical possibilities and capacities of both browsers and mobile devices are limited, especially when compared to a gaming computer or a gaming console, which had to be considered during implementation. In a learning environment with as many potential users as possible, the goal for the game must be to work on as many browser versions and mobile devices as possible, including not only high-end but also low-end devices. We had to consider and limit the graphical complexity of the scenes regarding graphical effects or special effects, for example, so as not to push the limits of lower-end hardware and devices. For the game mode "city" the overall technical workflow was to create the city in the 3D tool Blender in the form of several individual tiles (= pieces of the city with houses, streets, etc.), each modelled and created separately. Each tile was created in several versions to have different day times and lighting moods included in the final game. Furthermore, the game mode "city" was created in multiple tiles to allow for a dynamic effect of the icons and control elements. The individual tiles were rendered in Blender, different overlays (arrows, lightning bolts,

controllable menu elements, etc.) were created, and tiles and overlays were placed and pictured on top of each other inside the Godot game engine (see Figure 2).

We applied a similar approach for the game mode “manufacturing company”, where a 3D scene was created for each process (manufacturing hall, warehouse, and hydrogen plant) and rendered in several 2D planes that were placed on top of each other. With this approach, animations and movements could be included requiring less performance than actual 3D assets and scenes because the different planes could be moved in parallel with the screen, thus creating an animation (see Figure 3).

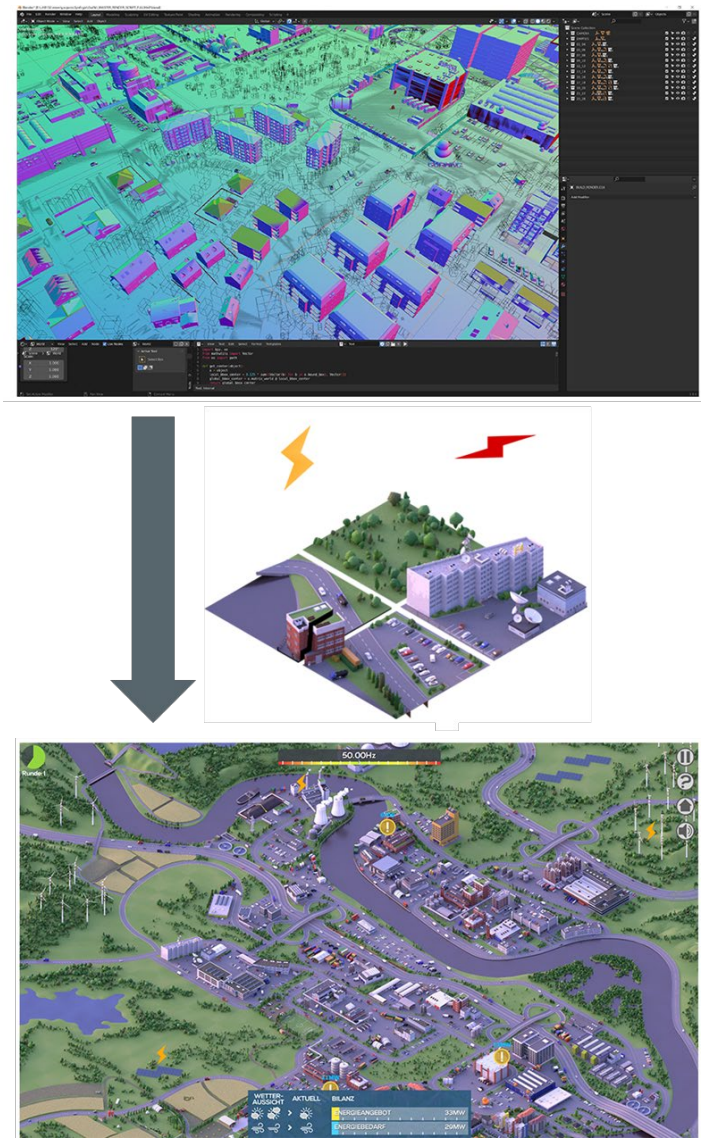


Figure 2: Conversion of 3D artifacts into segmented 2D images for a performant display in the application

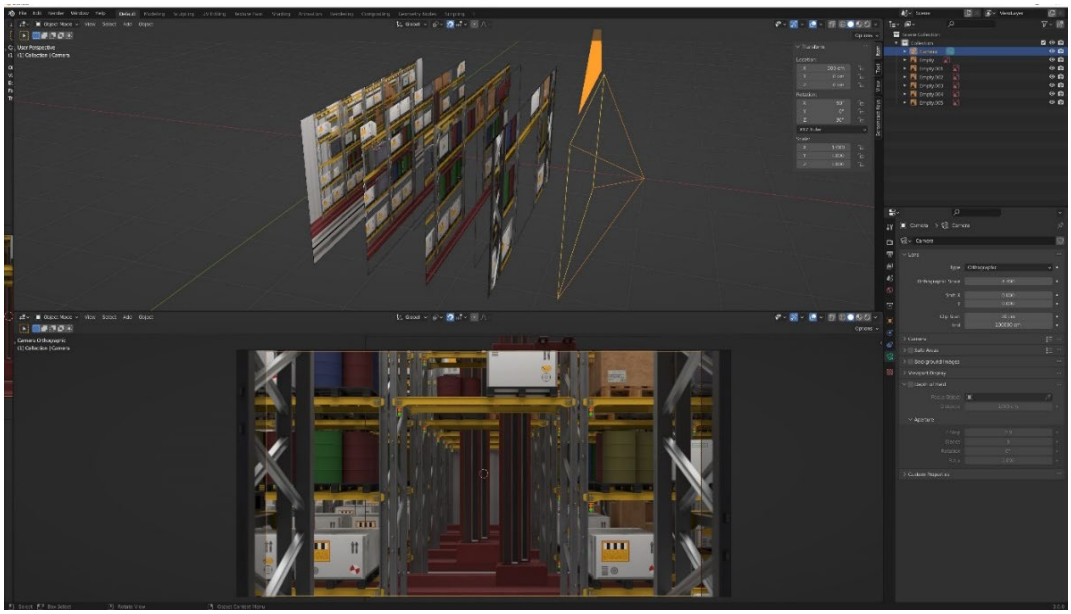


Figure 3: Image layers of an interior scene in which individual layers can be animated parallel to the camera

The same approach was used for the overview map connecting both game modes, where, for example, small vehicles are moving across the map. These 3D assets were rendered in several 2D planes, placed on top of each other, and then moved parallel to the screen to create movement (see Figure 4).



Figure 4: Individual images to animate the rotation of the vehicles on the overview map

SynErGame is available online as a browser game as well as a mobile app for Apple iOS and Google Android (SynErgie Project, 2022).

4. Application

As described in the requirements (see section 2.1), the entry barriers for SynErGame have to be low for being applicable for a broad audience. So far, SynErGame has been applied in lectures and seminars with students, as an opening for workshops with manufacturing companies, and for demonstration purposes at trade fairs. First insights gained from interviewing players afterwards are promising for SynErGame's further application:

- Students from two different universities emphasized the fun aspect of the game. Learning the subject matter worked almost incidentally; afterwards, major conclusions could be reproduced by the students.
- In workshops with manufacturing companies, the game was used with participants from different backgrounds (e.g., manufacturing managers with no energy background, energy managers with a strong energy focus). It has been shown that SynErGame is particularly suitable when only limited background knowledge is available. If an extensive background knowledge exists, the game is quickly reduced to the fun aspect and outperforming each other.
- At trade fairs, SynErGame has been used as an eye-catcher for the topic of industrial DR. The audience there was much more inhomogeneous compared to the students and workshops. It worked very well for game-affine and digital-affine visitors eager to get more information and stay in touch. However, with visitors non-affine and without appropriate background knowledge, starting a conversation was even harder since they possibly regarded industrial DR itself as a game.

An empirical evaluation of the game with quantified results is part of future work, as described in the next section.

5. Conclusion and Outlook

Within this paper, we proposed the approach and design of SynErGame as well as its implementation as a browser and mobile game. Building on the concept of industrial DR, an easy-to-use browser, and mobile gaming,

our approach fosters knowledge of industrial DR among a broad audience. First insights show that SynErGame is well accepted by a game-affine audience and an eye-catcher for more in-depth information on the topic.

For further work, an empirical evaluation of the game using the approach by Draghici et al. (2020) is planned. The evaluation results can be incorporated into further development. This includes a more detailed elaboration of target groups and their specific requirements. In addition, various levels of difficulty are planned to be created, for example by integrating further flexibility measures into the game mode “manufacturing company”.

Acknowledgements

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A Serious game to Teach About Career Pathways in the Games Industry

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Abstract: The games industry is one that continues to evolve and grow at an accelerated rate. Advances in technology in terms of how games are developed, the sophistication of gameplay, mechanics and their graphical representation span a multitude of game franchises. Furthermore, job roles within the games industry are as diverse as the game genres within it. One dilemma that sometimes confronts undergraduate game development students when entering university is what career path to undertake in the industry. Students in this discipline area are sometimes uncertain whether they want to pursue the aesthetical side of games development or implementational. When learning about the industry for the first time, it is important not only for students to be aware of the distinctive job roles within the industry but also how they interrelate with one another. From a higher educational standpoint, the concept of career pathways is associated with graduate employability. It is important to inform game development undergraduates from an early stage about the various routes into the games industry from a job role perspective. This paper provides a scoping overview of some of the salient job roles in the games industry and their associated hard and soft skill sets. Engagement with the literature associated with soft skills required for working in the games industry is presented. Focus is also provided on how to embed the concept of career pathways into games development higher educational curriculum. One proposed solution is the use of a serious game to teach students in this discipline about this topic. This paper also presents the development of a serious game designed to inform undergraduate game development students about different job roles within the games industry and what skill sets the industry requires. The paper advocates that a serious game can be one of many blended approaches to inform game development students about career pathways within the games industry. Acknowledgement is made that further empirical work is required to substantiate this pedagogical approach.

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

1. Introduction

The games industry is a global industry that continues to grow at an accelerated rate. According to NewZoo, in 2021, the global games industry was valued at $175.8m and is continuing to increase by 1.1% on an annual basis (ukiepedia, 2021). Furthermore, it has been stated that the video games industry, globally, will be valued at $217 billion by 2023 with the mobile sector leading the way (Aarki, 2020-21). This figure is expected to rise to $296 billion by 2026 (FutureLearn, 2021). The video games sector in the UK is the largest in Europe (TIGA, 2022).

Dundee is often perceived as being the hub of Scotland's gaming industry where DMA Design formed in 1988 and went on to create games such as Lemmings and Grand Theft Auto (TalentScotland, 2022). The games sector forms a substantial part of Scotland's creative industries with the creative industries being worth about £4.6 billion in value to the Scottish economy (Scottish Development International, 2022). The economic significance of the games industry globally as well as within Scotland and the UK in general cannot be overlooked. Technological advancements regarding the various game engines and software applications used to currently develop games means that they can accommodate a multitude of diverging game genres and platforms.

Developing games in a AAA studio involves the amalgamation and transparency of people working in different job roles and skill sets. There are a multitude of job roles within the games industry that range from the aesthetical to the implementation side of development. Some examples of such job role areas include game artist, game designer, game developer/programmer, animator, audio engineer, QA tester, producer, writer (Higginbotham, 2021). When commencing an undergraduate computer games development programme students in this subject area can at times be uncertain about what job role to pursue. Due to learning about the games industry for the first time, students are sometimes unaware of the diversity of job roles and the skill sets that accompany them. It is therefore important to inform undergraduate students about the concept of career pathways in the games industry from an early stage in their degree programme. A dilemma facing educators

teaching computer games development is how to embed the concept of career pathways coinciding with the concept of employability into course curriculum. This paper aim and value of this paper is to provide a review of some of the job roles within the games industry and identifies the key soft and hard skills associated with these positions. The concept of employability in relation to hard and soft skills is reviewed assessing the importance of these skills in the context of the games industry. The use of a serious game designed to inform undergraduate game development students about different job roles within the games industry is also presented.

2. Job roles within the games industry

According to TIGA (The Independent Game Developers' Association), the UK video games industry "…sustains highly skilled, graduate employment. A typical games development studio will have 80 per cent of staff qualified to degree level or above…". When working towards a degree on a games development programme it is important for potential graduates to be aware and familiar of the various job roles within the industry. Doing so at an early stage of their degree programme allows undergraduates to identify a chosen career pathway, allowing them to navigate towards their desired role within the industry. The BFI's Screen Business Report (2021), as mentioned by ukie, states that in 2019 the UK video games industry accommodated 73,370 full-time equivalent jobs (FTEs). 24,020 of these jobs were associated with developing and publishing roles. Choosing a games industry job role to work towards during a degree programme can be daunting if you are unaware of what positions there are and what skills you require excel in them. From a rudimentary perspective, job roles within the games industry can be split into two distinctive segments, namely, aesthetical and development. Categories within these segments include areas associated with predominately design and development.

One prevalent job position in the games industry is the role of games designer. According to Fullerton (2019, p. 3) a game designer *"… envisions how a game will work during play […] and is responsible for planning everything necessary to create a compelling player experience"*. The responsibility of the game designer is to create the *"structural elements of a system"* that when engaged by the players initiates the gameplay. Closely aligned with the role of game designer is the position of level designer. Within the games industry, level design is sometimes perceived as being applied game design where its aim is to *"… interpret the game rules, and to translate them into a construct (a level) that best facilitates play"* (Kremers, 2010, p.18). The main distinction between the two disciplines is that a level designer interprets the game rules, and a games designer formulates them (Kremers, 2010). Another aesthetical role in the games industry is that of artist often associated with creating concept art, storyboards, 2D or 3D characters and models for game environments. Where a game artist predominantly assists with the conceptual stage of design via the creation of assets for a game, it is the role of an animator to bring movement to the various assets and props within the game. Providing a good story and narrative to the game is the job of the game writer. Engaging backstories to a game can enhance the gameplay through interaction with characters such as NPCs (non-playable characters) contributing to the game's immersive focus. Focusing on the more development side of a game's team, job positions include audio designers, programmers, UI (user interface) designers and QA (quality assurance) testers.

3. Skills required for working in the games industry

The skill sets required for working in the games industry can be quite diverse particularly when considered from a technical perspective. When considering a career in the games industry predominant focus can at times be associated with technical skills and their relationship to the job role. It can however be argued that there are some generic skills sets that can be universally applied across job roles. Through the creation of online portfolios and showreels it is sometimes perceived that graduate applicants applying for jobs to game studios are already technically proficient. Technical skills are often equated with hard skills. However, in addition to being competent in hard skills such as programming, modelling, and design there is now an expectation that graduates progressing into the games industry require to be adequately equipped with soft skills. Undergraduates wanting to pursue a career in the games industry should be conscious that *"Games are rarely the product of designers' technical skills alone"* (Hamilton, 2019). It is important as educators to prepare graduates with work-ready skills and to address the "expectation gap" (McGill, 2008, p. 90) in terms of what industry requires from graduates in terms of being ready for working in diverse, fluctuating, and dynamic work environments. In providing a distinction between hard and soft skills, hard skills are associated with characteristics such as *"…drive, rigor, vision, intelligence, analytical, and technical skills"* whereas soft skills encompass attributes such as *"…motivation, empathy, self-awareness, self-regulation, and social skills"* (Marques, 2014, p. 146). Whilst it can be argued that job roles within the games industry are distinct though interrelated, there are generic soft skills required to work in a games development team.

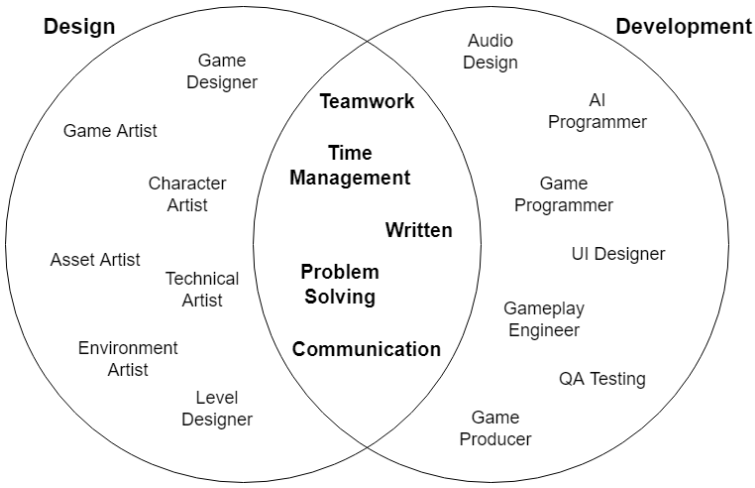


Figure 1: Soft and Hard Skills required in the Games Industry

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

3.1 Communication skills

Communication skills are important in the games industry due to the nature and composition of a games development team. For example, in the context of a game designer, it is important that you possess *"… the ability to communicate clearly and effectively with all the other people who will be working on your game"* (Fullerton, 2019, p.6). Not only is it invaluable to be able communicate your ideas to your team members you will also have to relay your ideas to staff members performing unique roles with different skill sets at various stages of the game's development lifecycle. Furthermore, there might be occasions where you may well have to pitch a game idea to directors in a studio. Communication skills are also relevant when having weekly team sprints where you will have to relay to the rest of the team what you have been working on in addition to updates on progress. In addition to being able to communicate, Schell (2020, p. 5) argues that the most salient soft skill associated with game design is listening. This will involve five different forms of listening that include listening to: (1) to your team when developing the game and making design decisions (2) your audience that will relate to those who will be playing your game (3) your game in becoming familiar with it having the ability to identify and issues or problems associated with it (4) the client who will be person paying to have your game designed and (5) your self in terms of self-reflection about what you are doing and why.

3.2 Written skills

Being able to communicate your ideas to members of your team using written skills is also important in the domain of game design. This could be in the form of the game or technical design documents. Other types of documents that are sometimes produced during the designing of a game can include documents relating to character design, world design, user interface, story and level progression and game script (Adams, 2014). Schell (2020) states that game documents serve two primary purposes, namely, memory and communication. These documents can become a collaborative process involving the contribution of many team members and in this sense can also aid towards accentuating team working skills. According to Macklin and Sharp (2016, p.134), design documents should be considered as *"living documents"* which should be kept current despite their constant revisions throughout the game design process.

3.3 Teamworking skills

"The creation of a video game isn't a solo project. It's the product of brainstorming, drafting, revising, and most importantly, teamwork" (Walsh, 2020). It is important that you can work well with your other team members when brainstorming and discussing design ideas. This also relates to team roles and responsibilities. Furthermore, "It is important for the team to recognize the shared and divergent values and goals of all team members" (Macklin and Sharp, 2016, p. 156). This is when the aspect of having a firm understanding of the different roles in a games team is required, reaching a consensus about design decisions, listening, and valuing the opinions of others throughout the game's development process. According to Schell (2020, p. 460) when making a game a team of "tremendous diversity" is essential and that team members will have "…very different backgrounds and value very different things". Possessing solid interpersonal and social skills are relevant to have

when resolving conflict within a project team. Soft skills of collaboration are required when resolving procedural, affective and substantive conflicts (Macklin and Sharp, 2016). Procedural conflicts are associated with processes in the way the team collaborates. Affective conflicts relate to personal aspects associated with team member's feelings, thinking and beliefs. Substantive conflicts are concerned with the game itself and potential conflict involving team member's divergent visions for the game.

3.4 Problem solving skills

The attribute of problem solving is also an important quality to possess when working in a game's development team. Reflecting upon issues of a technical nature that might involve a programming issue or an aspect of using a game engine and how to address them is a useful skill to have. For example, the concept of lateral thinking (Adams, 2014), is a skill that involves searching for alternative solutions and different paths to solve problems. Closely associated with this skill is that of analytical competence (Adams, 2014) having the ability to analyse and examine problems such as aspects relating to the design of the game.

3.5 Time-management

The ability to meet time critical deadlines is a relevant soft skill required when working in a game development team. The capability to be able to time and project manage your workload and deliverables is important to address the various milestones of the game's development. It is also relevant to be conscious of and to have a good awareness of the roles and responsibilities of your various team members. The reason being that project deliverables will be divided among team members differently and the time required to complete a certain task per member will vary (Macklin and Sharp, 2016). It is important to be understanding and considerate to your team members during the game design process, especially to those who might be under pressure with multiple deadlines.

4. Higher education, career pathways and the games industry

How to inform games development undergraduates about how the games industry functions, the different job roles within it and their overlapping necessity when designing a game can be considered as challenging. When devising a games development curriculum, it is important to ensure that the notion of employability is at the forefront. This is relevant to emphasise as it is the responsibility of educators to support undergraduates towards employability (Artess, Hooley and Mellors-Bourne, 2017). Furthermore, there is an importance on higher educational institutions to prepare their undergraduates for the world of work equipping them with the relevant graduate attributes required by their respective industries. The divergency of employability skills is something that can be associated with the notion of career pathways within the games industry. According to Harvey (2001, p.98), employability skills can be perceived as graduates possessing the salient skills they need, skills they have acquired beyond their generic attributes or graduate capabilities that an employer requires. Gunn, Bell and Kafmann (2010) argue that one challenge facing educators is that there is a need to ensure that in the context of employability, that the needs of employers are met through the employability skills cultivated in tertiary education.

Various approaches can be adopted towards educating and informing games development undergraduates about the necessary career pathways and skill sets required in the industry. We propose some recommendations to try and achieve this.

4.1 Guest talks from industry speakers

A useful approach towards solidifying lectures about the divergent job roles within the games industry is to invite guest speakers from the industry to talk to your students. Since the onset of Covid-19, this can be done remotely using Zoom or Microsoft Teams. Hearing from people who are employed in the games industry generically discuss about their job roles, the skill sets required for them and how they established themselves in the industry is highly engaging for game development students. Students can begin to understand the importance of working cohesively in a games team and how the various job roles interrelate in the iterative design and development process.

4.2 Events such as game jams and Transfuzer

Encouraging students to attend extracurricular events such as game jams or Transfuzer can provide undergraduates with good experience of working with other students from diverse backgrounds and skill sets. These events also provide students with core soft skills such as communication, teamwork, time management and general interpersonal and social skills to work in a team over a certain time.

4.3 Multidisciplinary team projects

The creation of course modules that involve students from different subject areas working together is a good way to inform them about the different roles in the games industry. For example, allowing game students to work with animation and music technology students will educate them about the demands of each job role and skill sets required to perform them. Allowing students to work in a team adhering to a project specification, will provide them with key soft and interdisciplinary skills. This could be achieved by allowing individuals within the team responsible for managing the project on a rotational basis.

4.4 Development of course curriculum

When developing course curriculum or a programme structure students need to be informed from their first year about what working in the games industry entails. It is important that they understand the multidisciplinary nature of the industry, the different job roles and skill sets required to work in it and how they all blend when working on developing a game. The concept of career pathways can be implemented throughout the remainder of their degree year allowing students to specialise in their chosen areas prior to graduation.

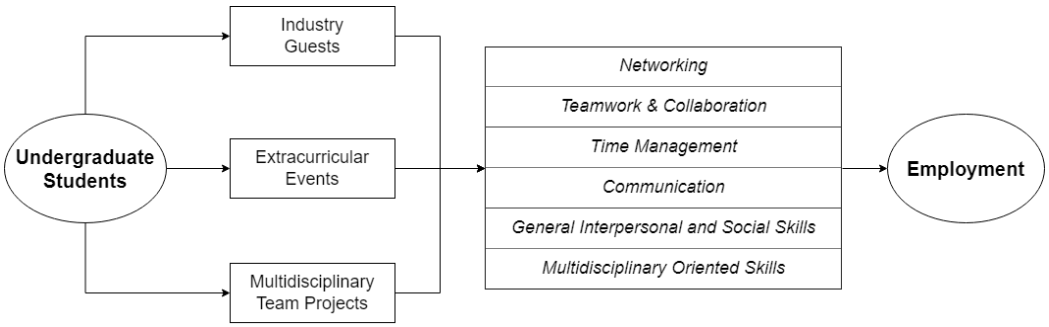


Figure 2: Teaching Undergraduates about Career Pathways and Soft Skills

5. Career pathways in the games industry: development of a serious game

The adoption of a serious game is a pedagogical approach that has been considered by the authors as a useful learning platform to inform game development students about the concept of career pathways. Serious games are games predominately designed for non-entertainment purposes. The implementation 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. The game will allow students to make sense and meaning of their continuing professional development and chosen career paths.

When considering how to teach the subject area of career pathways in the games industry the development of a serious game was a deemed to be a good justification. Several definitions of serious games exist in the academic literature. According to Dörner et al., (2016, p.3), a serious game can be defined 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."* Prior to commencing the development of the early prototype of the game, important consideration had to be given to the learning and assessment outcomes of the serious game in addition to the content integration. The development of the serious game was influenced by the game, "Game Dev Tycoon" which is a business simulation style game created by Greenheart Games. The basis of this game is that the player starts out developing games, gradually improving their skill sets, purchasing licenses for consoles, moving to office premises, and hiring staff.

5.1 Overall research aim

The primary aim of the research was to develop a serious game that would inform and educate undergraduate game development students about the different job roles in the games industry. Furthermore, the additional purpose of the game was to also educate students studying games development about the hard and soft skills required for working in the industry. The idea behind the game was also to inform students of the interrelationship and dependency of job roles when creating a game.

5.2 Gameplay aims

The gameplay aims of the serious game we proposed to develop were the following:

- To develop an entertaining and engaging game that embeds the concept of intrinsic motivation where students will play the game out of enjoyment, satisfaction, and fulfilment.
- Produce a balanced game with gameplay and mechanics that are straightforward to engage with in conjunction with the UX design of the game.
- Provide an element of challenge for the player with the embedding of puzzle and platformer elements to the game involving the player having to collect items in the studio to talk to the different NPC's.

5.3 Learning outcomes associated with the game

An important consideration related to the design principles of the game was that the gameplay provided the students with the opportunity to gain and retain knowledge about the industry. The primary pedagogical focus of the game was that of knowledge construction where it was important that the students were able to retain their knowledge learnt from the gameplay. It was therefore important that the basic gameplay and mechanics of the game adhered to the cognitive domain of Bloom's taxonomy. Learning through the gameplay would be enhanced through the theories of problem-based learning and reflection as the player progresses towards the various quizzes at the end of each level. Based on these factors, it was therefore deemed necessary that intrinsic motivation was facilitated and supported in the game. It was decided that the game would adhere to an endogenous educational game where the gameplay is informed by learning content and pedagogical theory (Winn, 2009). The learning outcomes of the game were as follows:

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

5.4 Content and assessment integration

One of the challenges associated with development of serious games is the aspect of integrating educational content. In the context of a serious game, "*The content of a game consists of assets, often designed by artists. Examples include avatars, houses, trees, other related objects, and sounds. At runtime, the content is brought to life by the game engine"* (Meham and Guthier, 2016, p.109). It was decided that the characterising goals of the game would be developed statically in tandem with the game's initial design until its completion (Mildner and Mueller, 2016). The intrinsic content of the game would adopt a linear and cyclical approach where the content moved the user along a defined path whilst embedding activities that impact on the gameplay (Aldrich, 2004, 2005). Learning will occur in the game via the incorporation of narrative and a dialogue system where the player will interact with NPC's (non-playable characters in the studio). The element of challenge will be facilitated through the gameplay where the player will have to solve various puzzles to navigate through the studio. Players will learn from each NPC about their job roles and the various skill sets required to perform them. Interacting, receiving, and digesting information from the NPC's will support the aspect of formative assessment with the quizzes at the end of each level accommodating summative assessment and student learning.

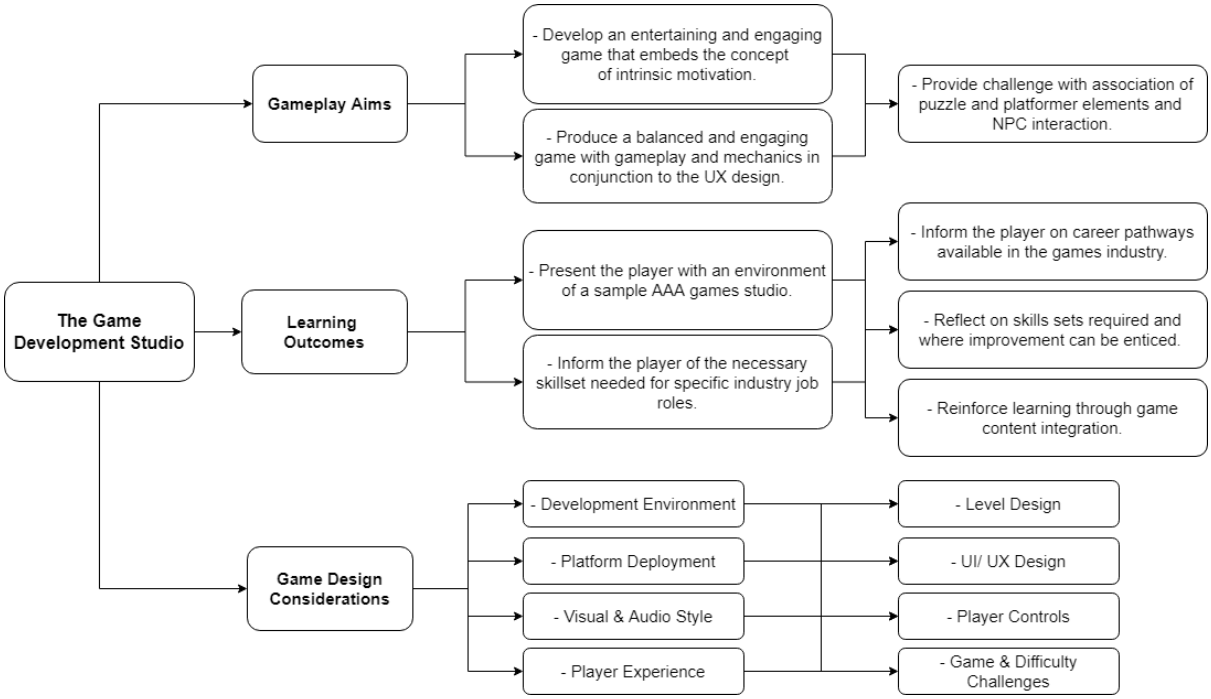


Figure 3: The Game Development Studio Game Considerations

5.5 Basic game design considerations

Some of the game prototype development decisions for the game are mentioned in table 1.

Platform	Windows PC
Development Environment	Unity Game Engine
Asset Packs used	Unity Asset store, Standard Assets from Unity
Visual Style	Realistic replication of games studio
Audio Style	Use of diegetic sounds
Level Design layout	Semi-linear and open layout
User Interface (UI) design	Clear and intuitive user interface
Controls	W,S,A,D and use of mouse
Player Experience	Immersive, replication of game studio
Challenge and difficulty	Puzzle elements, game narrative, Quizzes

5.6 Early visuals of prototype



Figure 4: Main menu of game

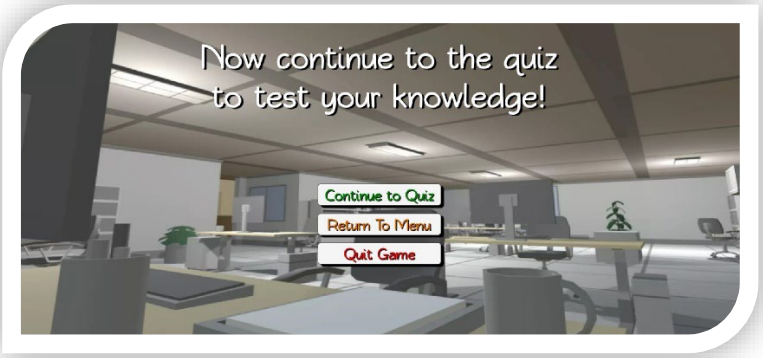


Figure 5: Commencement of quiz element of game



Figure 6: Example of interactive quiz

6. Future directions and developments of the game

The serious game presented in this paper is still at an early prototype stage with several improvements and development iterations required. The primary pedagogical aim of the serious game is to inform and educate game development students about the various job roles and skill sets required in the games industry. A basic game system has been utilised using the Snaps prototype office and distant land free characters from the Unity asset store. The rudimentary prototype of the game has been designed to test the feasibility of the game idea which has yet to be fully evaluated.

Future developments will involve enhancing the gameplay by including additional platformer elements at various stages of the game and a set of levels included in the game that the player must navigate through. The studio office environment will be redesigned with increased narrative and greater interaction with NPCs. It will be important to make the game fun and engaging for the player. Increased immersion in the game will be achieved through the inclusion of various genre elements such as platformer levels, the player having to search for clues and solve puzzles to talk to the NPCs.

The game will be evaluated from a mixed methods perspective utilising open-ended and closed questions in questionnaires designed to evaluate the gameplay and learning outcomes. Focus groups will also be employed to explore participant views based on the questionnaires. The focus groups will provide additional feedback designed to aid the continued iterative development of the game.

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Ganking the Ranking: The self-reported Learning Potential from a Selection of game Genres to Develop self-directed Learning

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Abstract: Game-based learning (GBL) is said to have encouraging potential for varying educational contexts and scenarios, but *how do practitioners select suitable edifying gaming content for their own unique environments?* Moreover, what are the correct strategies, recommendations, procedures and/or parameters for choosing appropriate gaming media for learning? There are countless options to choose from, varying in genre, play style, medium, difficulty, aim(s), etc. This paper presents the results of an interpretive study seeking to discern a set of requirements and qualities of informed GBL selection. Online surveys completed by history-for-education students at a South African Higher Education institution hope to bring us closer to guidelines for more effective GBL selection and application in tertiary education contexts across the globe. The following paper begins with remarks on the significance of self-direction in contemporary Higher Education and the potential for GBL to not only spur this tendency on, but to frame and support it. The conceptual framework used in the project is then unpacked as it relates to self-directed learning, game-based learning, video games and supplementary theoretical structures. The proceeding section is divided into three sections related to central study concepts, including: meta-behaviour, metacognition, and meta-emotion, with trial and error, observation and modelling, as well as reinforcement learning as subcategories of meta-behaviour that follow. Additional subcategories surrounding metacognition are then explored, namely: connected learning, reflect and improvise, logical and analytical reasoning, inquiry-based learning, and synthesis. The methodology then describes the hybrid video/survey techniques utilised to gather data relating to participant impression(s), motivational factors, challenge and educational value of GBL selection for Higher Education contexts. Results obtained provide a suitable starting point to construct a viable applied framework for such an environment.

Keywords: Game-based learning, game genres, self-directed learning, video games, history education

1. Introduction

Self-directed learning is a major field of study for 21st Century educationalists, and undeniably a critical skill in the labour market of a changing world. The modern world of work demands that people have demonstrable abilities to self-manage: their time and their inputs. Employees that can be tasked to solve a problem without micro-management and can be relied upon to use their resources responsibly and sparingly, are highly prized (Regan, 2003:593-599).

According to Loyens, Magda and Rikers (2008: 411-427), self-direction is a necessary skill in the world we are preparing our students for. However, the classroom culture that has been inherited is not designed around self-direction, and tends more towards compliant consumption, an un-flipped paradigm where students absorb what teachers say, and regurgitate it via essays, assignments and tests in order to demonstrate comprehension.

To combat this tendency, a Game Based Learning (GBL) approach is recommended. GBL has been a topic in learning for some time now. Most of the youth today all love playing games (Deterding et al., 2011: 14-17). The feeling of accomplishment, of improving, of beating an opponent, and the feedback and rewards that one gets are the sorts of things that keep one coming back for more. GBL can be great at tapping into intrinsic motivators where people are driving the direction of their own learning (ie. SDL). Done well, GBL can build on the foundations of intrinsic motivation by adding social connection and affords opportunities for extrinsic motivators such as leaderboards etc. A great GBL strategy can do wonders for user engagement (Hamari, Koivisto & Sarsa, 2014: 3025-3034).

To that end, this project wishes to address the need to develop self-directed learning among student teachers, with the aid of a GBL approach. The research question guiding this study is "What are the perceptions of 3rd year BEd History students in terms of Self-Directed Learning and the choice of video games, and how this could lead to effective GBL''? The main aim of the study is to establish and explore how the choice of video games could lead to effective GBL, that could lead to self-directed learning among 3rd year BEd students.

The main aim is operationalised in the following objectives:

- To understand the elements of self-directed learning and GBL.

- To determine why self-directed learning and GBL are important for 3rd year BEd History students.
- To establish how self-directed learning and GBL could be effectively developed in the History classroom.
- To establish what role video game choice plays in developing self-directed learning and GBL.
- To explore the student participants' perceptions and experiences regarding video game choice, whereupon it will be determined if certain SDL characteristics are visible.

2. Conceptual and theoretical framework

2.1 Conceptual framework

Three key concepts are central to this project, namely self-directed learning, GBL, and video games. All flow from one another, with self-directed learning being the central main theoretical underpinning.

2.2 Self-Directed Learning

In its broadest meaning, self-directed learning describes a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes (Knowles, 1975:18).

The characteristics of self-direction are:

- Self-direction as the continuous exercise by the learner of authentic control over all decisions having to do with learning; and
- Self-direction as the ability to gain access to, and choose from, a full range of available and appropriate resources (Knowles, 1975:18).

2.3 Game Based Learning

Definitions of game-based learning typically emphasise that it is a type of game play with defined learning outcomes (Shaffer, Halverson, Squire, & Gee, 2005). Usually it is assumed that the game is a digital game, but this is not always the case. A corollary to this definition is that the design process of games for learning involves balancing the need to cover the subject matter with the desire to prioritise game play (Plass, Perlin, & Nordlinger, 2010). This corollary points to the distinction of game-based learning and gamification. What exactly is meant by gamification varies widely, but one of its defining qualities is that it involves the use of game elements, such as incentive systems, to motivate players to engage in a task they otherwise would not find attractive. Similarly, there is an ongoing debate among scholars as to the exact definition of a game, and especially what is not a game (Salen & Zimmerman, 2004).

2.4 Video games

The following video games were shown to participants in the form of edited trailers (clips) and were questioned afterwards:

- *Assassin's Creed* (Ubisoft, 2007), a third person action game centred around the Medieval crusades;
- *Valiant Hearts: The Great War* (Ubisoft Montpellier, 2014), a puzzle adventure game set during the First World War;
- *Crusader Kings III* (Paradox Interactive, 2022), a grand strategy game set in Medieval Europe;
- *Ghost of Tsushima* (Sony Interactive Entertainment, 2020), an action-adventure game which interprets the Mongol invasion of Japan;
- *Total War: Rome II* (Sega, 2013), a tactical strategy game revolving around the ancient world, where players control a wide range of ancient nations, focusing on economy, military, and political strategies; and
- *Age of Empires III* (Microsoft Game Studios, 2005), a real-time strategy game with the colonial period as back drop, players control European, native American, and African nations in the additional content packs released for the game (DLC).

3. Theoretical framework

Self-directed learning emphasises the choices in one's learning path; in effect, intrinsic motivation as critical for self-directed learning (Loyens, Magda, & Rikers, 2008). Self-directed learning can be defined as "a process in which individuals, with or without the help of others, take the initiative in diagnosing their learning needs, formulating objectives, identifying human and material resources, selecting and implementing effective learning

strategies, and evaluating outcomes "(Knowles, 1975, p. 18). The learners need to be encouraged to take their own learning decisions in self-directed learning (Downes, 2010). Evidently, informal learning provides much more learning opportunities. People may feel demotivated to learn at school because there are constraints that could interfere with their motivation, such as demands to complete tasks without the resources available in the classroom (Wolters, 2011).

Zap and Code (2009) have been reviewing the self-directed learning of video game environments and gives a comprehensive discussion on the regulatory mechanisms of self-regulated learning, along with the self-efficacy of learners, self-determination, motivation, interest, intention, aptitude, goal and task orientation, self-awareness, metacognition, and other theories of self-regulatory learning. The design characteristics of game environments which supported self-directed learning were explored, such as the characteristics of an authentic learning environment which first involved simulating the real-life context in which students took decisions in a secure setting without any repercussions. Second, students are involved in genuine tasks in a simulated setting where transferrable skills have been learned. Third, via observing and modeling, students learned via GBL. Fourth, students have taken on diverse responsibilities in exploring and developing different concepts.

This section explains how the self-directed learning model is developed from player experience. It is structured in terms of “meta-behaviour”, "metacognition”, and “meta-emotion”. Meta-behaviour is thinking about doing and includes the subcategory of “trial and error”, “observation and modelling”, and “reinforcement learning”. Metacognition is thinking about thinking and includes the subcategories of “connected learning”, “reflect and improvise”, “logical and analytical reasoning”, “inquiry-based learning”, and “synthesis”. Meta-emotion is thinking about feelings and includes the subcategories of “dissatisfaction and anger” and “curiosity and satisfaction”.

Table 1: Self-directed learning strategies in GBL

Meta-Behaviour	**Definition**
Trial and Error	A low-order learning strategy involving an unsystematic self-directed learning process.
Observation and Modelling	Modelling occurred when the participant learnt through observing and imitating others' actions without deep understanding.
Reinforcement Learning	Learning occurred when the participant reflected on behaviour that was extrinsically motivated (Deci & Ryan, 2013) by a reward.
Metacognition	**Definition**
Connected Learning	Learning occurred when the participant could connect game features with their interests (Deng *et al.*, 2016) or prior or existing knowledge.
Reflect and Improvise	Learning occurred when the participant was faced with an unfamiliar or nonroutine game event as compared to the rest of the game.
Logical and Analytical Reasoning	Learning occurred when the participant constructed or inferred a hypothetical situation to reason about potential and enacted in-game actions.
Inquiry-Based Learning	Learning occurred when the participant actively adopted various problem-solving skills to solve problems or discover new knowledge.
Synthesis	The highest-order learning strategy that involved selecting, evaluating, reflecting, and integrating information into a coherent whole.
Meta-Emotion	**Definition**
Dissatisfaction and Anger	The learner felt dissatisfied when an unexpected event occurred during a fight, and a second-order emotion of anger was aroused.
Curiosity and Satisfaction	The learner was intrinsically motivated (Deci & Ryan, 2013) to learn by curiosity.

4. GBL Factors promoting Self-Directed Learning

Based on the study of the player experience (Toh, 2018), this section suggests some relevant factors that game designers and educators can consider when creating games to promote self-directed learning in video games in pedagogical contexts. These factors include providing "learning analytics as a metacognitive tool", "gradual release of new information over time", "a safe space", "defamiliarisation mechanics", and "scaffolded learning".

Table 2: Factors which promote self-directed learning.

No.	Factors Promoting Self-Directed Learning
1	Learning Analytics and Data Visualisations
2	Gradual Release of New Information Over Time
3	A Safe Space to try Multiple Approaches and Learn from Failures
4	Defamiliarisation Mechanics
5	Scaffolded Learning: An In-Game Companion

The following section outlines the methodology used in this study.

5. Methodology

A qualitative, phenomenological design is chosen. Phenomenology is an approach to qualitative research that focuses on the commonality of a lived experience within a particular group. The fundamental goal of the approach is to arrive at a description of the nature of the particular phenomenon (Creswell & Poth, 2016). Typically, interviews are conducted with a group of individuals who have first-hand knowledge of an event, situation or experience. The interview(s) attempts to answer two broad questions (Moustakas, 1994): What have you experienced in terms of the phenomenon? What contexts or situation have typically influenced your experiences of the phenomenon (Creswell & Poth, 2016)? Other forms of data such as documents, observations and art may also be used. The data is then read and reread and culled for like phrases and themes that are then grouped to form clusters of meaning (Creswell & Poth, 2016). Through this process the researcher may construct the universal meaning of the event, situation or experience and arrive at a more profound understanding of the phenomenon.

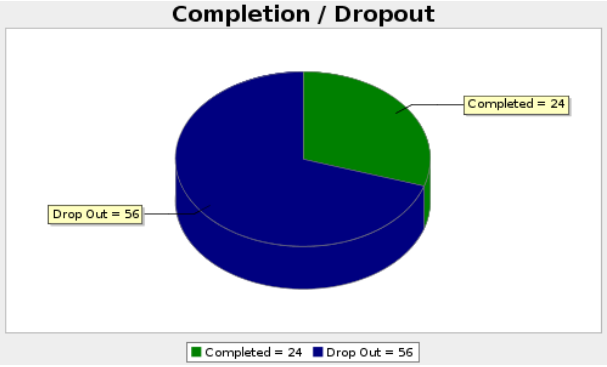
The target population for this research are all BEd students in South Africa. As it will not be possible to do research with all these students, the study population only included 3rd year History BEd students in the Faculty of Education at the *North-West University*, on the Vaal Triangle Campus. Due to time and logistical constraints, a non-probability, convenient, purposive sample of thirty 3rd year BEd students from the North-West University on the Vaal Triangle Campus will be used. Non-probability sampling is a sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected (Leedy & Ormrod, 2005; De Vos & Strydom, 2011).

Purposive sampling refers to selecting participants for a specific purpose (Leedy & Ormrod, 2005; De Vos & Strydom 2011). In the case of this study, the researcher purposively focused on 3rd year History BEd students. The sample could also be considered convenient, as the participants are located on the same site where the researcher works. The 3rd years chosen are part of the researcher's module HISE 322. N=80 3rd year students

will be chosen, as possible deficiencies and weaknesses in relation to the development of self-directed learning could be identified during their studies at Higher Education level, and action plans to address the deficiencies and weaknesses during their four years of study be put in place before they complete their studies and enter their teaching careers.

A series of videos and descriptions of Historical and history-for-education adjacent video games have been presented to the participants. These videos will acquaint the students with the various types of video game genres that exist. The videos will showcase gameplay of the games, as well as some of the narrative stories of the games. The data collection strategy that will be used are one-on-one interviews with open and closed-ended questions at the end of the video game intervention. Interviews will be conducted with the selected student participants at the end of the intervention, in order to understand their perceptions regarding appropriate video games for GBL and SDL.

6. Quantitative data analysis and interpretation



Viewed	Started	Completed	Completion Rate	Drop Outs (After Starting)	Average Time to Complete Survey
188	**80**	**24**	**30%**	**56**	**23 minutes**

Figure 1: Survey completion rates, drop outs and average length to completion.

Of the total 80 students, only 24 completed the survey, with a dropout after starting at 56 students. It took approximately 23 minutes to complete the entire survey on GBL choice. The following graphs and tables analyse the first question that was asked in the GBL choice survey, namely "What was your initial reaction to the video game presented above?". Students had to score their satisfaction with the specific game trailer watched on a scale of 1 to 5, 1 being very unimpressed to 5 being very impressed.

Table 2: What was your initial reaction to the video game presented above? (*Assassins Creed*)

	Answer		Count	Percent
1.	Very Unimpressed		1	2.78%
2.	Unimpressed		2	5.56%
3.	Neutral		6	16.67%
4.	Impressed		10	27.78%
5.	Very Impressed		17	47.22%
	Total		**36**	**100%**
Mean: **4.111**	Confidence Interval @95%: **[3.764 - 4.458]**	Standard Deviation: **1.063**	Standard Error: **0.177**	

Student participants responded to the *Assassin's Creed* trailer very favourably as evident from the data obtained in the visualisations above. 47.22% were very impressed, while a further 27.78% were impressed. The average mean score out of 5 was 4.111, the second highest score for all 6 games used in the study. The standard deviation for this question was 1.063, while the standard error margin was 0.177.

Table 3: What was your initial reaction to the video game presented above? (*Valiant Hearts: The Great War*)

	Answer		Count	Percent
1.	Very Unsatisfied		3	12.50%
2.	Unsatisfied		4	16.67%
3.	Neutral		3	12.50%
4.	Satisfied		11	45.83%
5.	Very Satisfied		3	12.50%
	Total		**24**	**100%**
Mean: **3.292**	Confidence Interval @95%: **[2.785 - 3.799]**	Standard Deviation: **1.268**	Standard Error: **0.259**	

Student participants responded to the *Valiant Hearts: The Great War* trailer with mixed reactions as evident from the data obtained in the graph and table above. 45.83% were satisfied, while a further 12.50% were very satisfied. 12.5% were neutral, a further 16.67% were unsatisfied, while a further 12.5% were very unsatisfied. The average mean score out of 5 was 3.2.9.2, the lowest score for all 6 games used in the study. The standard deviation for this question was 1.268, while the standard error margin was 0.259.

Table 4: What was your initial reaction to the video game presented above? (*Crusader Kings III*)

	Answer		Count	Percent
1.	Very Unsatisfied		0	0.00%
2.	Unsatisfied		2	10.00%
3.	Neutral		4	20.00%
4.	Satisfied		11	55.00%
5.	Very Satisfied		3	15.00%
	Total		**20**	**100%**
Mean: **3.750**	Confidence Interval @95%: **[3.377 - 4.123]**	Standard Deviation: **0.851**	Standard Error: **0.190**	

Student participants responded to the *Crusader Kings III* trailer with positive reactions as evident from the data obtained in the graph and table above. 55% were satisfied, while a further 15% were very satisfied. 20% were neutral, while a further 10% were unsatisfied. The average mean score out of 5 was 3.750, the 3rd lowest score for all 6 games used in the study. The standard deviation for this question was 0.851, while the standard error margin was 0.190.

Table 5: What was your initial reaction to the video game presented above? (Ghost of Tshushima)

	Answer		Count	Percent
1.	Very Unsatisfied		1	6.25%
2.	Unsatisfied		1	6.25%
3.	Neutral		1	6.25%
4.	Satisfied		8	50.00%
5.	Very Satisfied		5	31.25%
	Total		**16**	**100%**
Mean: **3.938**	Confidence Interval @95%: **[3.387 - 4.488]**	Standard Deviation: **1.124**	Standard Error: **0.281**	

Student participants responded to the *Ghost of Tshushima* trailer with very positive reactions as evident from the data obtained in the graph and table above. 50% were satisfied, while a further 31.25% were very satisfied. 6.25% were neutral, while 6.25% were unsatisfied while a further 6.25% were very unsatisfied. The average mean score out of 5 was 3.938, the 3rd highest score for all 6 games used in the study. The standard deviation for this question was 1.124, while the standard error margin was 0.281.

Table 6: What was your initial reaction to the video game presented above? (*Total War: Rome II*)

	Answer	Count	Percent
1.	Very Unsatisfied	2	11.76%
2.	Unsatisfied	2	11.76%
3.	Neutral	3	17.65%
4.	Satisfied	7	41.18%
5.	Very Satisfied	3	17.65%
	Total	**17**	**100%**

Mean: **3.412**	Confidence Interval @95%: **[2.804 - 4.019]**	Standard Deviation: **1.278**	Standard Error: **0.310**

Student participants responded to the *Total War: Rome II* trailer with mixed reactions as evident from the data obtained in the graph and table above. 41.18% were satisfied, while a further 17.65% were very satisfied. 17.65% were neutral, while 11.76% were unsatisfied while a further 11.76% were very unsatisfied. The average mean score out of 5 was 3.412, the 2nd lowest score for all 6 games used in the study. The standard deviation for this question was 1.278, while the standard error margin was 0.310.

Table 7: What was your initial reaction to the video game presented above? (*Age of Empires III*)

	Answer	Count	Percent
1.	Very Unsatisfied	0	0.00%
2.	Unsatisfied	0	0.00%
3.	Neutral	1	5.88%
4.	Satisfied	11	64.71%
5.	Very Satisfied	5	29.41%
	Total	**17**	**100%**

Mean: **4.235**	Confidence Interval @95%: **[3.968 - 4.503]**	Standard Deviation: **0.562**	Standard Error: **0.136**

Student participants responded to the *Age of Empires III* trailer with extremely positive reactions as evident from the data obtained in the graph and table above. 64.71% were satisfied, while a further 29.41% were very satisfied. Only 5.88% were neutral, while there were no unsatisfied or very unsatisfied responses. The average mean score out of 5 was 4.235, the highest score for all 6 games used in the study. The standard deviation for this question was 0.562, while the standard error margin was 0.136.

The following section reports on the qualitative data obtained from the participants in the open survey. Each question is handled separately, and the video games are also discussed separately.

7. Qualitative data analysis and interpretation

7.1 Question 2: What factors influenced your initial impression?

7.1.1 Assassin's Creed (Game 1)

Regarding the factors that influenced the participant's impression while watching the *Assassin's Creed* trailer, one participant remarked about how he had played the game before: 'I grew up playing this game on my phone, seeing it brought back memories'. Another participant shared her thoughts on the type of game *Assassin's Creed*

is: 'It's not a game I would play or want to play so I didn't really enjoy it'. Another participant alluded to his knowledge of historical techniques and that the look of the game appealed to him: 'First and foremost I know the setting of the story from the game itself, I like the graphics and the ancient techniques they used'.

7.1.2 Valiant Hearts: The Great War (Game 2)

With reference to the factors that influenced the participant's impression while watching the *Valiant Hearts: The Great War* trailer, a participant remarked that the storytelling approach appealed to him, by saying: 'The narrator at the beginning makes one want to know more about the storyline of the game'. This is echoed by another participant, who remarked: 'I am impressed by the way the game explains the great war by not only sticking to the war but incorporating a love story to keep players intrigued'.

7.1.3 Crusader Kings III (Game 3)

Regarding the factors that influenced the participant's impression while watching the *Crusader Kings III* trailer, a participant liked how the story was delivered, by stating: 'The woman at the beginning narrates the story and we are shown how to play the game'. This is echoed by another participant, who said: 'That mother and son still hold grudges for what they did to the father', and another: 'seeing the snake on top of the baby made me feel scared', showcasing some emotional response.

7.1.4 Ghost of Tshushima (Game 4)

When analysing the factors that influenced the participant's impression while watching the *Ghost of Tshushima* trailer, a participant noted his love for anything related to Samurai, by stating: 'I love Samurai games'. This is echoed by another participant, who loved the setting, but also remarked on the visuals of the game: 'The graphics and the storyline of the samurai during the Mongol invasion, as well as the open-world adventure aspect'.

7.1.5 Total War: Rome II (Game 5)

Regarding the factors that influenced the participant's impression while watching the *Total War: Rome II* trailer, several factors were evident based on responses. One participant liked the specific historical period depicted, by saying: 'That it is based in Rome'. Another participant appreciated the strategic element of the game, stating: 'The strategy aspect of the game influenced my initial impression'. Another participant liked the visual elements of the game, saying: 'Graphics and layout of the video, content and characters'.

7.1.6 Age of Empires III (Game 6)

With reference to the factors that influenced the participant's impression while watching the *Age of Empires III* trailer, participants mentioned content related factors such as: 'The fact that the game is about Empires'. Another pointed specifically to the fact that Africa was represented in the game, stating: 'I am really intrigued by the fact that they used Africa in the game'.

7.2 Question 3: Does this game motivate you to learn more about the subject? Why/Why not?

7.2.1 Assassin's Creed (Game 1)

Regarding whether the game motivated participants to learn more about the subject while watching the *Assassin's Creed* trailer, a participant stated that games can make History come alive, by saying: 'Yes. Because the game makes you as the player to experience how it was during the time of the events of the game, so it will make the theory content come to reality'. Another concurred, by saying: 'Yes...this game is based on real history events that happened long ago, so playing it will help you understand how different events unfolded'.

7.2.2 Valiant Hearts: The Great War (Game 2)

With reference to whether the game motivated participants to learn more about the subject while watching the *Valiant Hearts: The Great War* trailer, a participant noted that she wanted to know more, stating: 'Yes I would like to find out what causes are the causes of the war'. Another participant noted the dialogue mentioning trenches, which interested her: 'Yes it motivates me cause at least I can hear they talk about the trenches'.

7.2.3 Crusader Kings III (Game 3)

When analysing whether the game motivated participants to learn more about the subject while watching the *Crusader Kings III* trailer, a participant was intrigued by the drama present in the game, saying: 'Yes it does, because it explains better more about the crimes committed and seeking for revenge. In history we learn more

about that'. Another liked the aspect of the ruling monarchy, saying: 'Yes because it highlights historical rule of kings and queens'.

7.2.4 Ghost of Tshushima (Game 4)

Regarding whether the game motivated participants to learn more about the subject while watching the *Ghost of Tshushima* trailer, a participant noted his fondness for Japanese culture, stating: 'Yes, I want to know more about history of Japan and samurai'. Another participant was more critical, saying: 'No Because it doesn't connect to any historical context'.

7.2.5 Total War: Rome II (Game 5)

With reference to whether the game motivated participants to learn more about the subject while watching the *Total War: Rome II* trailer, a participant was motivated by the storyline, saying: 'Yes to find out what happened to the king and the lady who was laying on the floor'. Another participant disagreed, saying: 'No, the game was not marketed right and that trailer was vague'.

7.2.6 Age of Empires III (Game 6)

When analysing whether the game motivated participants to learn more about the subject while watching the *Age of Empires III* trailer, a participant noted that the game could help understand specific content, saying: 'Yes it will help me learn about Ethiopian war'. Another participant agreed, saying: 'Yes I am motivated to learn about the African Royals, I think as an African it is nice to know the history of your continent before I can take interest in other continents'.

7.3 Question 4: Does this game look challenging to you? Why/Why not?

7.3.1 Assassin's Creed (Game 1)

Regarding whether the game looked challenging while watching the *Assassin's Creed* trailer, a participant noted the puzzle solving looked interesting, saying: 'No. It is interesting as I like games that are about solving different missions and help people'. Another disagreed, saying controlling the action may be a problem, stating: 'Yes it does I might not be able to play it because I think it is hard to control the person fighting'.

7.3.2 Valiant Hearts: The Great War (Game 2)

With reference to whether the game looked challenging while watching the *Valiant Hearts: The Great War* trailer, a participant noted that unpredictability looked difficult, saying: 'Yes the game looks challenging because the survival of soldiers is not guaranteed so outcomes of the game might be unpredictable'. Another participant noted that the trailer had a lot of things going on, stating: 'Yes it does because there are so many things happening at the same time'.

7.3.3 Crusader Kings III (Game 3)

When analysing whether the game looked challenging while watching the *Crusader Kings III* trailer, a participant noted the seemingly challenging progression, saying: 'Yes. Because you have to go through different stages and challenges in order to be granted the power of being a king'. Another participant disagreed, saying the game gives you enough information to succeed, by stating: 'No, because everything was explained very well, they fully explain how to defeat your opponent'.

7.3.4 Ghost of Tshushima (Game 4)

Regarding whether the game looked challenging while watching the *Ghost of Tshushima* trailer, a participant noted that the game may need some skills, stating: 'Yes it looks challenging and interesting and it needs survival skills in order to win'. Another participant disagreed, citing personal experience with this type of genre, saying: 'No, these types of games are my specialty and I enjoy them a lot'.

7.3.5 Total War: Rome II (Game 5)

With reference to whether the game looked challenging while watching the *Total War: Rome II* trailer, a participant noted that there was an apparent lack of clarity on what was expected, saying: 'Yes, it's not clear what the players mission entails'. Another participant agreed it looked challenging, but for this person, the strategic depth was more of a concern, stating: 'Yes it does look challenging because the premise of it is strategy it requires critical thinking'.

7.3.6 Age of Empires III (Game 6)

When analysing whether the game looked challenging while watching the *Age of Empires III* trailer, a participant noted that the game is easy if you have subject knowledge, saying: 'No it doesn't if you have a history background'. Another participant agreed that the game looked easy, but cited the easy controls, stating: 'No, it seem very user-friendly, and accessible'.

8. Conclusion

Participants who viewed trailers for six historically themed and history-for-education adjacent video games varied in their responses to the snippets of content shown to them. Initial responses were largely positive for each game shown. Game 5 (*Total War: Rome II*) received the most mixed reviews from participants, while Game 1 (*Assassin's Creed*) received near critical acclaim from participants. Satisfaction alone does not inevitably make a piece of edifying media appropriate, however. The results of more in depth questioning is presented below to complete the picture:

Initial impressions of game trailers viewed were influenced by, among other things, factors such as: *nostalgia* (Game 1), *genre* (Game 1, 3 and 6), *fidelity* (Game 1 and 5), *theme* (Game 1 and 6), *story* (Game 2 and 5), *framing* or *content delivery* (Game 2 and 6), *emotional response* (Game 2), *aesthetics and art style* (Game 2 and 5), *narrative elements* (Game 3), *familiarity with various content elements and/or setting(s)* (Game 4 and 6), *game focus/aim* (Game 5 and 6), and *relationship with daily activities* (Game 5). Each of these could aid educators in selecting apposite gaming media for education and/or history education.

Patterns also emerge when considering motivation to play or engage with the games shown. Incentives and drives including: *immersion* (Games 1 and 3), *accuracy* (Games 1 and 4), *appropriateness* (Games 1 and 6), *content* (Games 1, 3 and 5), *narratology* (Games 2 and 6), *game focus* (Game 2 and 6), *clarity* (Game 2 and 6), *level of control* (Game 3), *learning potential* (Games 3 and 6), *familiarity with content* (Game 4), *relevance to user* (Games 4 and 6), *intrigue* (Game 5), *overall game appeal* (Games 3 and 5), and *depth* (holistic vs shallow) (Game 5). These motivational factors should be further explored to determine their priority when selecting GBL for education. This forms the foundation of a framework for appropriate GBL selection in the classroom.

In terms of challenge, abundant aspects arise when considering GBL selection. Participants proposed elements such as: *puzzle solving* (Game 1), *critical thinking* (Games 1, 4 and 6), *difficulty* (Games 1 and 4), *control and input* (Games 1 and 6), *unpredictability* (Games 2 and 5), *clutter* (Game 2), *progression* (Game 3), *degree and depth of information given* (Games 3, 5 and 6), *strategy* (Game 3), *user interface and experience (*Games 3, 5 and 6), *skill requirements* (Games 4 and 5), *genre* (Game 4), *ergonomics* (Games 5 and 6) and *point(s) of reference* [background knowledge] (Game 6). These factors affect the approachability of a piece of media chosen for GBL—the degree to which will be measured in a future paper.

Finally, several interesting considerations surface when considering the appropriateness of the presented games for GBL, namely: *emotional affectation(s)* (Games 1 and 5), *relatability* (Games 1 and 2), *authenticity* [including violence, realism] (Games 1, 3 and 6), *utility* [relevance to topics being explored] (Games 1, 5 and 6), *analytic value* (Games 2 and 3), *salience* [degree to which a game can attract and retain attention] (Games 2 and 6), *depth* (Game 3), *auxiliary factors* [other skills/topics that can be transferred] (Game 3), *curriculum fit* (Games 4 and 6), *arousal* [curiosity, interest] (Game 5), and *overlap with other histographies* (Game 6). These factors form a checklist for edifying value and GBL selection.

A conceptual framework can now be constructed and translated into an applied framework by way of future work and testing with other game formats (tabletop games), types (simulations, training media, serious games) and test populations. An integrative literature review would also allow the researchers to compare and contrast results obtained here with work done by others. Future work from the current authors will explore these avenues and more to formulate a comprehensive framework for GBL selection in the Higher Education milieu.

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Playing for Privacy Awareness: Learning from a "Wow-Moment" with iBuddy

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Abstract: iBuddy is a narrative game-based simulation session inspired by research evidence and designed to enhance secondary school and higher education students' privacy awareness. Students enter the simulation through storytelling and are asked to install the iBuddy app. Later in the simulation, students discover that some of their personal information have been extracted from their devices and manipulated – and this generates a *wow-effect* that sparks questions and discussions. The simulation is backed-up by a lively debriefing phase, supported by original animation videos, interactive activities, and small group games. To overcome privacy issues, iBuddy sessions are played on a local network and the collected data, which are anonymous, are deleted before the end of the session. iBuddy exploits an original software, released as open source, with a layered architecture composed by app, server and operator interface. The system also includes an Artificial Intelligence filter for inappropriate content. Multilingual class materials are published under a Creative Commons license and are available on the www.protectyourdata.ch platform. Post-session assessments collected from over 970 students indicate that they enjoy iBuddy sessions and learn from it. Follow-up assessment data, collected on a portion of the participants, also suggest that iBuddy sessions are effective and conducive to medium-term behavioral change.

Keywords: Privacy education, privacy awareness, simulation, app, secondary education, higher education.

1. Introduction: the challenge of privacy awareness

In the age of digitalization our personal information is continuously exposed on digital devices and networks: privacy concerns each of us. Data privacy is "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others" (Westin, 1967, p.7) Privacy is related with freedom and justice (Kimmel, 1988) and it is a central issue in the progressive digitalization of our society, balancing the power of the Big Tech and of platform capitalism (Srnicek, 2017). Formal education systems included privacy in most digital competence frameworks (e.g., Carretero, Vourikari and Punie, 2017; UK Dept. of Education, 2019). Personal data management, identity management and data protection are, under different names, constituents of active digital citizenship (Carretero, Vourikari and Punie, 2017; JISC, 2014; Guitert, Romeu and Baztan, 2017).

Privacy education initiatives strive to make young people aware of the technical and financial processes that involve our personal data, of our digital traces and profiles (Andreoletti et al., 2020; Eke, Norman, Shuib and Nweke, 2019), and of their value as the "new oil" (Humby, 2006; Giordano et al., 2020). Nonetheless, scholars have identified the so-called *privacy paradox*: although users are generically worried about privacy, many tend to accept disclosure of personal data in exchange of services or popularity (Norberg et al.,2007; Kokolakis, 2017; Barnes, 2006).

In this paper we present the design, development, delivery and assessment of iBuddy, a 2-hour interactive class simulation-based session developed to let young people wonder about personal data capture and storage and to stimulate privacy learning and awareness raising.

2. State of the art

2.1 What we know about privacy awareness

Research evidence supports the claim that most internet users do not consider privacy risks in their behavior, as they are not really aware of them (Ferrari, Puccinelli and Giordano, 2015; Zyfallari, 2021; Andreoletti et al., 2020). Users grant access to personal and sensitive information even to apps that capture considerably more data than actually needed for the services they provide (Vidas, Christin and Cranor, 2011; Felt et al., 2011; Agarwal and Hall, 2013). In many cases, users lack the knowledge and skills to manage their privacy settings (Aditya et al., 2014; Park and Jang, 2015), are seldom aware of relevant regulations and of the economic value of their data (Acquisti, Taylor and Wagman, 2016). However, when they are properly informed, many act consequently (Zyfallari, 2021). For example, in a recent study about 80% of the respondents modified the privacy settings of their social media accounts or reduced their social media usage to feel safer (DuckDuckGo, 2019).

The privacy awareness landscape is heterogeneous. In 2019 a survey with over 20'000 participants from 21 countries reported that in some countries including India, France and the UK, over 50% of the population demonstrated privacy awareness, while several other countries, including the USA and China, seem to lag behind (Statista, 2019).

2.2 Disclosure, rewards, sensitivity and visibility

Despite the evidence of a general increase in privacy awareness, it has been observed that Internet users still tend to accept the disclosure of personal data in exchange for some rewards, without actually wondering how the data will be used and to what purposes. It is interesting to notice that data have economic value for the platforms that collect them, while the nature of user rewards is mostly symbolic (e.g., popularity on social media), thus generating a peculiar asymmetry. We translated these insights into iBuddy's instructional approach: providing participants with an opportunity to experience first-hand the effects of the exposure and capture of personal information that they considered safe. iBuddy aims to generating surprise or, as we labelled it, a *wow-effect* (Kamstrupp, 2016) that facilitates learning.

Pursuing the *wow-effect* required identifying specific situations that would be perceived as risky. A measure of privacy risks can be obtained by combining two main factors (Aghasian et al., 2017): (a) sensitivity, i.e., a measure of how confidential data are; and (b) visibility, i.e., the perceived ease of access to the data. In our work, we considered these two features to develop the simulation. In particular, the iBuddy session stirs students with highly sensitive and apparently difficult to extract data such as pictures from their smartphones.

3. iBuddy

The Making A Privacy Aware World (MAPAW) project, funded under the Agorà Program of the Swiss National Research Foundation, aims to promote personal data protection awareness in young people between 16 and 20 years old. iBuddy was designed and developed as a major action of the MAPAW project.

Thanks to an additional funding by the Swiss national platform Jugend und Medien, some of MAPAW's instruments were adapted and delivered also in lower secondary schools (age group 12-15).

3.1 Instructional principles

The instructional design of iBuddy relies on two assumptions that summarize the discussion above:

1. Deep awareness should be based on factual knowledge (Botturi, 2004): before complying with a list of "do's and don't's", young people need to understand how technologies work and learn to make informed decisions.
2. Generic justice and freedom issues are important, but young people will perceive the relevance of data protection only in relation to personal situations in which sensitivity and visibility are at stake.

At the outset of the project, a design dilemma was identified: research evidence indicates that, in order to make privacy issues relevant, the students' personal experiences and data should be addressed; at the same time, we knew from experience that it is difficult to discuss in class possibly delicate personal situations.

The solution was to transport the activity with the magic circle of a game, more specifically a narrative-based simulation (Betrus and Botturi, 2010), which creates a safe learning environment (Rudolph, Raemer and Simon,

2014; Botturi and Loh, 2009). The personal data of the participants in an iBuddy session become part of a game in which the main character is somebody else – namely a fictional AI-enhanced android classmate.

Game-based learning materials are not new in privacy education, as both class games (Mediasmarts, n.d.; ATED, n.d.) and online games (JRC, n.d.; TSR, n.d.; CISA, n.d.). Such games simulate security threats, but do not directly involve the players and their devices or data: they rely on *understanding* security issues, not on directly experiencing it. A few online games involve players' data and devices: the award-winning *Take this lollipop* (https://takethislollipop.com/) and the more recent *ClickClickClick* (http://clilckclickclick.click). While both share the active engagement-approach, they only work on computers (not on mobile) and are not connected with lesson plans or other instructional materials.

3.2 iBuddy session design

iBuddy sessions are led by a *presenter*, who stands in front of the class and interacts with the students. S/he is supported by an *operator*, who sits at back of the room and manages the iBuddy system. A typical session takes 2 class periods (about 90 min.) and is articulated in the following 6 phases.

Phase 0 | Introduction. The presenter welcomes the students with a predefined narrative, as represented in Figure 1. Students are invited to download and install the iBuddy app, which is a regular Android and iOS app. If some students do not have a smartphone or do not have the permission to install new apps, they can still participate working in pair with a classmate.

> Welcome, my name is [name]!
>
> Before we start, I need you to agree to keep secret what you will experience in the next two hours. In fact, your class has been selected among many for a cutting-edge technological experiment.
>
> In a few weeks, you will welcome a new classmate – but he (or she!) will be special. Indeed, s/he will be a synthetic buddy, made of advanced carbon biotechnical body animated by sophisticated artificial intelligence algorithms. This new buddy will blend in and make your class and your school much better.
>
> Our task today is to configure your new synthetic buddy: determine if it is a boy or a girl, his or her tastes, and so on. In order to do this, we will use a special app.

Figure 1: Narrative introduction to the iBuddy session

Phase 1 | Creating a profile. Once everyone is ready with the app, the presenter unlocks the session. The app behaves as a regular app: it prompts the permission screen for accessing the user's contact list and picture gallery. Students can grant or revoke access, as they like; if asked, the presenter only says: "Feel free to do as you usually do in such cases". The app then asks users to fill in their profile, choosing nickname, favorite food and sport, and adding a profile picture. After that, the app shows eight *basic buddies*, i.e., standard androids with basic features like gender, race and one personal characteristic, e.g., "listener", "patient", "creative", etc. To avoid direct resemblance to real people, the basic buddies are represented in cartoon style (Figure 2).

While students fill in their profile, the iBuddy app copies too the iBuddy local server a sample of 6 pictures from each user's gallery, his/her contacts list, and data on installed apps and their usage time. After pictures have been filtered by an AI algorithm (see below), the *operator* can view the collected data.



Figure 2: Screenshot of the basic buddy profiles

Phase 2 | Class questions. In this phase the wow-effect is generated. Once everyone has picked their favorite basic buddy profile, the app informs the participants to pay attention at the presenter: the configuration procedure now requires the whole group to find collective answers to a few questions. The system resorts here to two different types of questions:

1. *Standard questions* are ready-made and generic and include items like "How many girls are in your class?", "How many of you play soccer?", or "How many of you have a pet?".
2. *Custom questions* are created on-the-fly either by the system automatically or by the operator, using the participants' personal data that the system has collected. A sample of custom questions are presented in Figure 3.

Thanks to the system interface, the presenter can sequence standard and custom questions according to the class reactions. The appearance of supposedly private data on the screen generates a powerful wow-effect, and 3 or 4 custom questions are enough to generate a deep and rich discussion in the following phases. Based on experience and feedback, pictures with simple "everyday" portraits, pets or food are safe and generate a powerful wow-effect. On the other hand, landscapes or objects do not seem to produce a suitable reaction. The session is always concluded with one or two standard questions to chill out the class.

Data used	**Sample custom question**
Installed apps	15 of you use Whatsapp. Shall your new buddy also use this app?
Usage data	On average, you use TikTok 30 hours every month. This is about 1houd a day! Will your new buddy also be such an eager tiktocker?
Contact list	Manu has over 215 contacts in her phone. Will your new buddy also be so popular?
Picture gallery	Deb seems to like pets. Will your new buddy also share this passion? 

Figure 3: Sample custom questions.

Phase 3 | Meet the iBuddy. Eventually, the system then generates the iBuddy profile, which is based on the answers provided in phase 1. The iBuddy is presented to the class (with some fancy visual effects), as in Figure 4. The iBuddy is the MacGuffin that sets the whole session in motion and the actual result, although often welcomed with thrill, is not very important for the learning process. The simulation ends here.



Figure 4: Presentation of the customized buddy.

Phase 4 | Debriefing part A: behind the scenes. Simulation-based and game-based learning is triggered by playing but is made solid by debriefing (Betrus and Botturi, 2010; Peters and Vissers, 2004). The debriefing of an iBuddy session happens in two steps. In the "behind the scenes" step the students are led to interrogate the simulation: what "tricks" let the system grab their data to generate custom questions? The presenter explains how the app accessed and transmitted personal data to the local server, and that this is what many apps also do. The system includes a summary interface that shows the key figures of the collected data. Reflections on how such data can be fed into AI algorithms to infer additional digital profile details are also brought in. Eventually, the presenter clicks on "the red button" and deletes all personal data from the iBuddy server.

Phase 5| Debriefing part B: our data on the Internet today. The second debriefing step explores how personal data are collected, stored and elaborated in real life. It focuses on regular and legal uses of personal data (e.g., personalized advertisement) rather than on malicious uses (e.g., identity fraud), and its structure depends on the questions the participants ask. For this part, the presenter is equipped with modular original learning materials, including a set of 4 short digital stop-motion video clips, groupwork activities and a list of useful websites. All original materials are available at www.protectyourdata.ch in Italian, French, German and Rumantsch under a CC License. The platform also provides a database of useful privacy education resources.

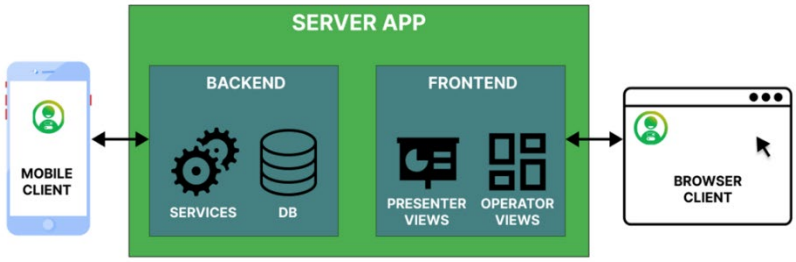
4. Software design and implementation

The iBuddy system is composed by two main software applications (apps): a Server app and a Mobile app. The Server app is a web-based software responsible for the data processing (backend) and that allows presenter and operator to interact with captured user data (frontend). The Mobile app is the software that students interact with, and it is compatible with both iOS and Android smartphones.

4.1 Functional and technical architecture

The technical architecture of iBuddy was devised to provide a smooth, entertaining and technically safe session. The functional architecture is composed by three parts, as in Figure 5:

1. A Mobile app (client) which students interact with, that manages the data collection (contacts, pictures, applications list, applications usage) during the session. The Client features a multi-language interface.
2. A Server App that receives and processes the collected data. The server is composed of two sub-components: (a) the Backend, that manages the collected data, performs statistics, generates questions and filters content; and (b) the Frontend, that allows presenter and operator to access Backend services via web views, i.e., interfaces and data visualizations.
3. A Browser Client to access the Frontend web views.



1.

Figure 5: Representation of the iBuddy functional architecture, composed of mobile app, backend, frontend and browser client.

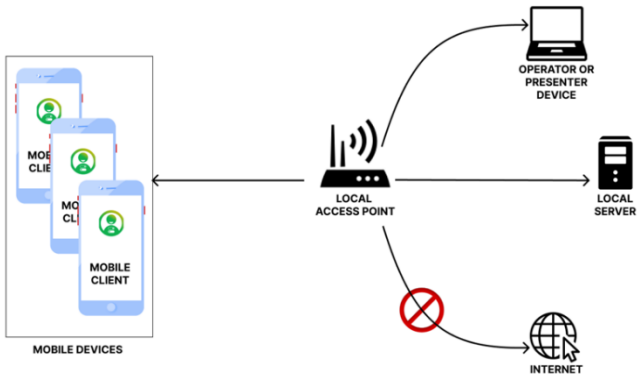


Figure 6: Representation of the physical architecture, composed of a local access point to which students and presenter/operators connect and a local server for data storage and processing.

The physical architecture includes at least the following devices (Figure 6):

1. Mobile devices: students' mobile phone(s), running the iBuddy Mobile app.
2. Operator and Presenter devices: a device through which presenter and operator access the Frontend.
3. Local Server: a desktop or mobile computer where the iBuddy server runs. This can be a separate computer or the computer used by the operator or the presenter.
4. Local Access Point: a device that manages the local network with no internet access. The users' devices and the local server are connected to the local network and disconnected from the Internet to avoid any unauthorized access or leak of the data collected during the session.

4.2 Web views

The Frontend component exposes several web views. The most important ones are the presenter view, that allows the Presenter to lock/unlock the session, to show/hide questions and introduce the final iBuddy; and the Operator view, which allows to create and edit custom questions by using collected pictures from students' devices (Figure 7).

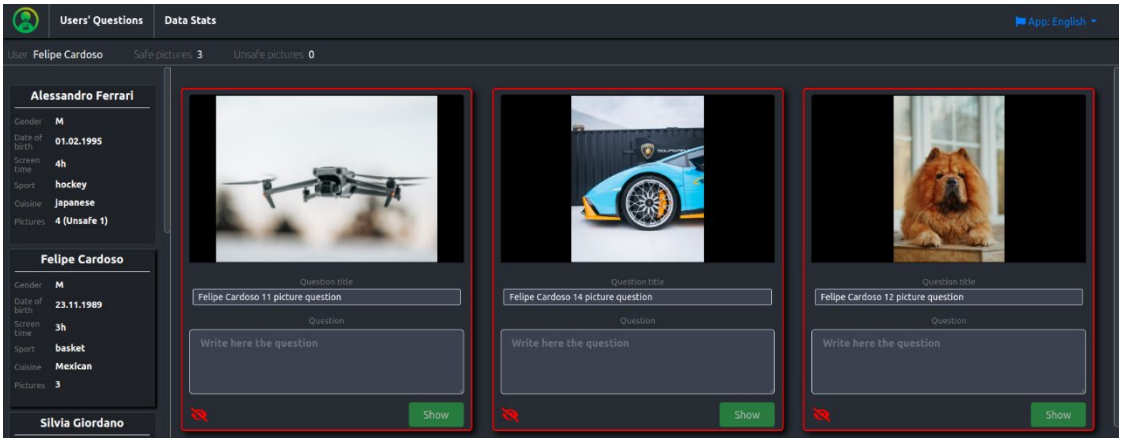


Figure 7: A screenshot of the operator view.

4.3 Services

Besides simple data management, the Backend component provides three additional main services:

1. Statistic. The statistics service extracts insights from the collected data, i.e., contacts, pictures, installed apps and apps usage. The goal of this service is to provide materials for generating custom questions during Phase 2 and to show students an overview of the collected data in Phase 4.
2. Questions generation. The questions generator is a service that periodically computes statistics and automatically creates questions about some interesting figures, like the average number of items in contact lists. Specifically, the service generates custom questions by selecting and filling generic question templates based on the outcomes of the statistics service. Templates are provided in multiple languages.
3. AI Unsafe Content Filter. The content filter is a service that constantly monitors all the pictures collected from the users' devices and checks if any of them contains unsafe content. The service is powered by an

AI-trained model, from NSFW JS library creators1, which classifies images in the following categories: drawings, hentai, sexy, porn and neutral. As it can be observed from the confusion matrix in Figure 8, the model is capable to identify the correct category with a high accuracy (always greater than 91% across all the considered categories). The performance of the model is depicted by the confusion matrix in Figure 8. Only the images classified as "neutral" will be made available to the operator, while the remaining ones are discarded. To reduce the likelihood of false negatives (i.e., images that are wrongly considered neutral by the model), we set a safety threshold on the score associated with the neutral class, selecting only images with neutral score above 0.55 (on a 0-1 range).

5. Legal aspects

Collecting students' data from their smartphones for teaching purposes might seem ethically extreme. Actually, the data collection happens every day with many commercial applications and web services: the whole point with iBuddy is making the process visible by completing it in a short time and inside the classroom. iBuddy was designed to meet the requirements of the Swiss Federal Act on Data Protection[2] and respect ethical standards.

Swiss laws do not set a minimum age for consenting to data processing, which depends on "discernment capacity". As a solution to this issue, we developed a clear and full explanation of the iBuddy system and of the way data are processed throughout the simulation for the school's headmaster and for the teacher in charge, who must be in class during the simulation.

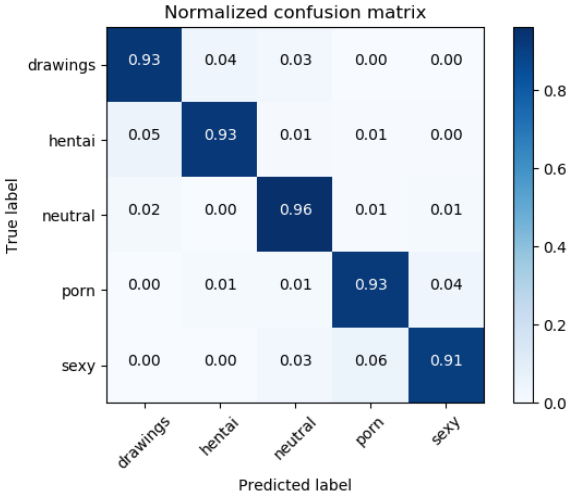


Figure 8: Confusion matrix of the AI-based model trained to detect inappropriate images.

Moreover, each student is free to access the privacy policy properly attached to the iBuddy app, which is available anytime. Students can also grant separate and specific consent for access to the photo folder and the contacts list of her/his phone. Without explicit consent, the operator is not allowed to capture and process any photo and/or contact item, the system not being even able to access them. During the sessions held so far, part of the pupils granted their consent while others denied it with varying proportions in different classes, and the presenter took this as an opportunity to discuss the consequences of granting and denying consent for data processing.

Even if the aim of the simulation is to achieve a wow-effect, we published a proper, easy to understand privacy policy to comply with the law, and part of the debriefing is indeed also about going through it to raise awareness about this important but often neglected text.

When starting the simulation, the app prompts the user to write a nickname. This choice, instead of the actual name, was done so that neither the presenter nor the operator could connect the data to any subject.

[1] https://github.com/infinitered/nsfwjs
[2] Federal Act on Data Protection of 19 June 1992 (RS 235.1)

As mentioned above, data are kept in a single copy on a local server with no Internet connection, so that no interference with unauthorized third parties is possible. Last but not least, all personal data are deleted during the session itself, which usually means about 30 minutes after their collection.

6. Experimentation and lessons learned

Between March 2021 and March 2022, 52 iBuddy sessions were carried out, engaging a total of 978 students in 17 schools, as illustrated in Table 1. Students engaged deeply (even asking if they would actually welcome a synthetic buddy in their class!) and, during the debriefing, asked many questions and mentioned personal experiences. Both students' and teachers' informal feedback was positive, at times enthusiastic.

Table 1: Schools, classes and students by school level

	Secondary school		High school	University	TOTAL
Age range	11-12y	13-14y	15-19y	20+	
Classes/Groups	20	11	17	4	52
Students	344	219	343	72	978
Schools	10		6	1	17

6.1 Post-session feedback

A short post-session survey was used to collect structured feedback. It was composed by 4 closed and 4 open items and was administered during the last 10 minutes of every session. Closed questions were rated on a 1 (lowest)-to-10 (highest) scale, and the evaluation items were:

1. Enjoyment: how much did you enjoy this activity?
2. Usefulness: how useful is this activity in raising awareness among young people about a responsible use of their personal data?
3. Involvement: how involved did you feel in these issues?
4. Importance: how important do you think the topics are?

All participants across all school levels found the topic of data privacy very *important* (M=8.96) and the activity very *useful* (M=8.58) and *enjoyable* (M=7.82), consistently indicating that iBuddy sessions achieved their immediate goal. The breakout of the different school levels (Figure 9) reveals that younger participants have weaker personal involvement. The global average score for *involvement* is overall lower (M=7.09) and increases with the age of the participants. A possible explanation is that high school students more often own personal devices and have at the same time more sophisticated behaviors and less parental guidance.

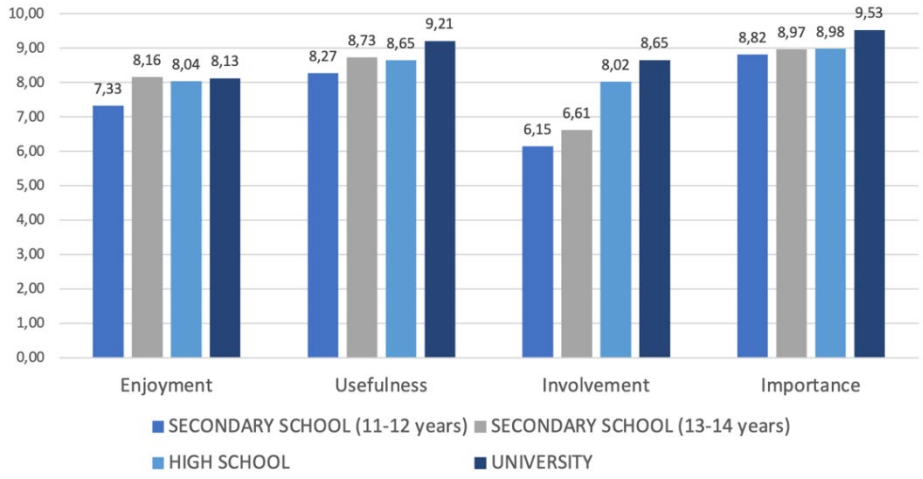


Figure 9: Average scores obtained in the various categories (N=978)

The answers to the open questions suggest that students appreciated the simulation. This very interactive part aroused interest and some participants felt personally touched when their personal data (especially photographs) appeared on the screen in front of everyone. Many students claimed to have been surprised by the ease and speed with which their personal data were captured and appreciated the fact that iBuddy reproduced a similar experience to what happens in real life with apps and social networks. After an initial moment of disorientation, the students quickly realized that their data were not being "hacked", but rather that

they had actively granted access when they had accepted (without reading!) the terms of use of the iBuddy application. Such element of awareness is of course crucial to promote privacy awareness.

Moreover, many participants realized for the first time the economic value of their personal data, which is often underestimated, and were amazed to find out what really goes on behind the scenes of their mobile phones. In the debriefing, the students appreciated the animated video clips, the activities carried out in groups and the discussions established with the presenter.

6.2 Follow-up assessment

Positive post-session feedback not necessarily corresponds to actual long-term learning. Two months after each session, the secondary school participants received an invitation to fill in a short follow-up survey. 563 participants were contacted, and 22% responded (N=124, 57 males and 67 females). The follow-up survey included 7 items starting with "After the iBuddy session…", for which respondents indicated the level of agreement on a 3-point Likert scale, ranging from "like before" (value 0) to "much more than before" (value 2):

1. … I pay attention when I install a new app
2. … I read or at least screen the terms of use of the apps I install
3. … I check and adjust privacy setting for my social network accounts
4. … I select what I post or share on social networks
5. … I think about why some ads appear when I browse the web
6. … I check and maybe delete cookies on my devices
7. … I am generally aware about my personal data

While the general item "I am more aware about personal data" received the highest impact score (1.15), lower scores were measured for more specific items (Figure 10). This corresponds to previous findings and to the privacy paradox idea. In general, participants seem to pay more attention to frequent active behaviors (e.g., adjusting privacy settings; selecting content to post; etc.), and less to rare passive ones (e.g., managing cookies; reading terms of use; etc.). Adding up all the seven scores, it is possible to calculate a unique indicator ranging from 0 to 14. Interestingly, only 20 participants (16%) have a high score (>9) and 14 are girls.

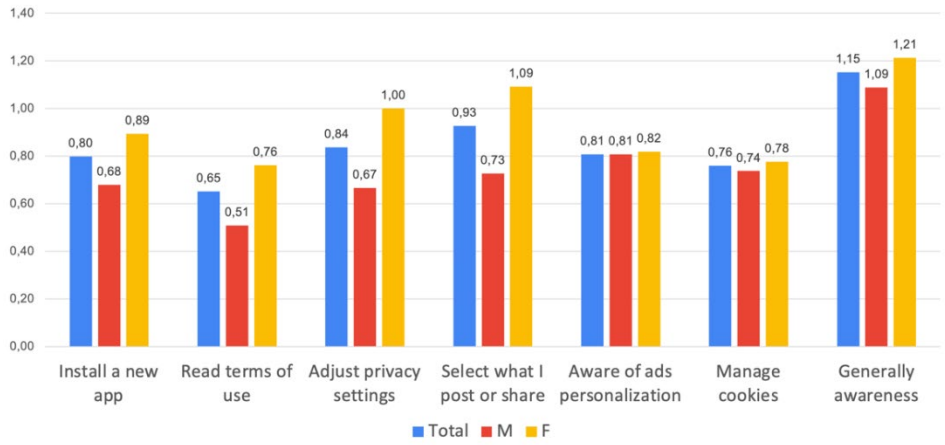


Figure 10: Follow-up survey data (N=124)

7. Discussion and conclusions

This paper presented iBuddy, a narrative simulation that promotes privacy awareness in secondary and higher education students. The iBuddy system and the 2-hour session in which it is used were designed based on research evidence in privacy awareness, and its positive post-session and follow-up assessment results confirm the effectiveness of its approach.

iBuddy is an ongoing project. On one hand, we are currently working to make the system and its related teaching and learning materials easily accessible in multiple languages. This includes both making the iBuddy system downloadable and providing it on light-weight hardware (e.g., Raspberry). On the other, we are fine-tuning the session design in two directions: (a) developing different narratives, that might be more appealing and engaging for different target groups; (b) designing a "closed" session in which students do not use their personal devices.

This latter situation can better meet the regulations of individual schools or school systems, and clears all potential legal issues connected with accessing student data during the simulation.

Overall, the iBuddy experience provides evidence that a game-based approach can be effective to tackle complex and potentially delicate learning topics, such as privacy and personal data protection, promoting engagement and medium-term behavioural changes.

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A Game-based Approach for Open Data in Education: A Systematic Mapping Review

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Abstract: Open Data is defined as digital data that is made available with the technical and legal characteristics necessary to be freely used, reused, and redistributed by anyone, anytime and anywhere. Examples of Open Data can be data on mobility or pollution, which an increasing number of cities are making available to citizens. In education, the novel field of Open Data has the potential of empowering a young generation with digital skills and critical thinking through work with real-life Open Data. However, the scarcity of methods and tools for skills development and insertion into educational designs reduces the possibility of achieving this potential. This study is part of the project ODECO, aimed at addressing challenges in the creation of Open Data ecosystems in several contexts, such as education. A systematic mapping review was conducted to uncover the research connections between Open Data education and educational games. Twenty-eight studies were identified and analysed through iterative searching and including keywords related to Gamification, Open Data and Education. In doing this, relevant themes and novel approaches in the current literature were found. This paper discusses how the fields of Open Data education and educational games methodologically and theoretically contribute to outline a game-based approach for Open Data in education. An Open Data Gamified Education Framework leads to authentic learning experiences for real-world problem solving in relation to eight actions: connecting classroom activities to real facts, empowering students to act with Open Data, supporting technical Open Data skills in the classroom, building literacy and developing skills, enhancing civic participation, creating more realistic and appealing narratives, extending teaching outside the classroom by collecting data in real time and local settings, and increasing engagement and motivation.

Keywords: Game-based learning, Open Data, Education, Skills development, Real-world problem solving

1. Introduction and background:

In recent years, the field of Open Data research has expanded into a growing number of research domains, such as policy studies and education (Conradie & Choenni, 2014; Sieber & Johnson, 2015). Open Data strategies are now seen in several different contexts, such as local governments making openly available datasets on social and technical aspects of the city and therefore permitting citizens to freely use, modify and share them (van Loenen et al., 2021). Although Open Data might enhance transparency and accountability in fair and innovative societies, current systems are focused on the data release process, lacking awareness on how Open Data is useful and valuable to users (Bachtiar et al., 2020; Hellberg & Hedström, 2015; van Loenen et al., 2021; Veljković et al., 2014). In order to counter current challenges, there is an increasing call for strengthening a user-centred perspective connected to a broader public engagement (Conradie & Choenni, 2014; Kassen, 2013; Prieto & Rodriguez, 2012; Robinson et al., 2009; Shadbolt et al., 2012; van Loenen et al., 2021). However, the integration of several interest groups implies the development of new Open Data approaches and skill sets. Users need to have the appropriate skills and competencies to use and modify available Open Data and understand what kind of perspectives it opens (Conradie & Choenni, 2014; Kassen, 2013; Prieto & Rodriguez, 2012; Shadbolt et al., 2012).

To assure the inclusive development of Open Data, The International Open Data Charter suggests engaging with schools to incorporate Open Data into educational curricula (International Open Data Charter, 2015). Although previous experiments using Open Data in education have shown how Open Data contributed not just to developing digital capabilities but also to enhancing 21st century skills on students, these have also elaborated on a lack of approaches for implementation (Coughlan, 2019; Saddiqa et al., 2019a; Saddiqa et al., 2021a; Atenas et al., 2015). Despite current challenges, there are indications that lead to authentic learning experiences (Herrington et al., 2014) and active learning theories (Romero et al., 2014).

Game-based Learning (GBL) is grounded in active learning methodologies and encourages learning activities by building on engagement and challenges (Romero et al., 2014). Educational games help to make the knowledge that is abstract and common for experts more concrete and embedded in a situation (Gee, 2006). Authentic learning is a pedagogical approach that situates learning tasks in the context of future use, helping students to transfer robust knowledge to real-life practice (Herrington et al., 2014). One of the main focus points in the

development of science game formats over the past 20 years has been how the medium of games can introduce new approaches to authentic science education (Gee, 2003). Prime examples of this are profession simulation games that simulate some of the objectives and environments of a specific profession by using the technology, tools and/or methods of that profession. As a result, the medium of games has been used to create environments with simulations of complex real-world situations, where students must think like professionals and solve problems in innovative ways, just as professionals do (Clinton & Rieber, 2010; Oh, 2011; Shaffer & Gee, 2005). The authentic approach has been extended in recent years with the so-called scientific discovery games or citizen science games, where gamers contribute to real world research as part of gaming (Cooper et al., 2010; Good & Su, 2011).

The research aim of this paper is to explore the novel field of Open Data education and the connection to educational games to outline a game-based approach for Open Data in education. A systematic mapping review was conducted to understand how connections between the two fields have been explored and to outline potentials for future development of Open Data gamified education. This study is part of the Marie Skłodowska-Curie Innovative Training Network ODECO, which is aimed at addressing challenges in the creation of user driven, circular, skill-based and inclusive Open Data ecosystems (ODECO – Towards a Sustainable Open Data ECOsystem, 2021).

2. Methods:

A systematic mapping review method (Grant & Booth, 2009) was applied to map out and categorise existing literature that connects Open Data education and educational games. The process involved three steps. Firstly, defining the scope of the review and defining keywords; secondly, identifying potential studies through literature searches and thirdly, determining the studies to be included in the in-depth review. The review was conducted across the Scopus database (Scopus, 2022).

The following figure provides an overview of the steps, and findings of the systematic mapping review process. Three search sets were defined to map different components and possible relations within the fields. An initial review led to 62 records, after applying inclusion criteria, this number was reduced to 28 studies. According to Gough et al. (2003) an in-depth review of each study was made to analyse them following a process of screening and categorisation.

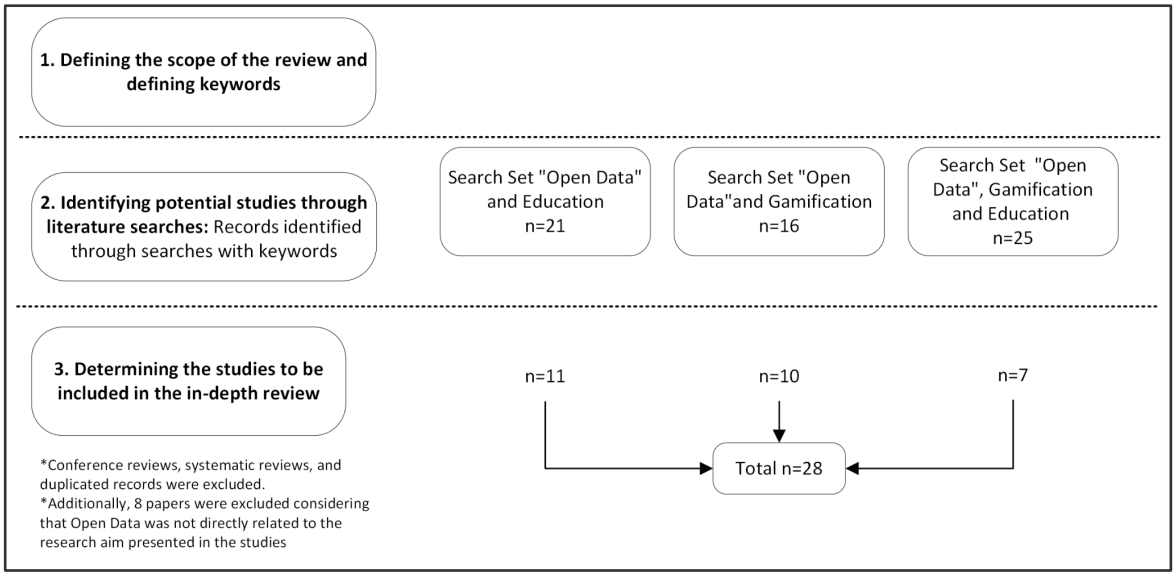


Figure 1: Overview of systematic mapping review process and findings

2.1 Systematic mapping review process:

The systematic mapping review process started defining the scope. With the aim of capturing different perspectives in current literature between Open Data education and educational games. This review looked at exploring the connection between three topics: *Open Data, Education and Gamification*. Keywords were chosen based on a screening of concepts that are referred to in primary research articles in this new field. The following keywords were chosen:

Table 1: Keywords used for searches.

Topic 1:	**Topic 2:**	**Topic 3:**
Open Data Open Datasets	School Classroom Educational resource	Gamification Game-based learning Games

Iterations of searches with various combinations of keywords and screening of titles and abstracts were conducted to enable an overview of the field and ensure the identification of the maximum number of articles showing different connections between Open Data education and educational games. Considering the exploratory aim of the systematic mapping review, three search sets were established to explore different approaches to the field: (1) *Open Data and Education*, (2) *Open Data and Gamification,* and (3) *Open Data, Education and Gamification.* The following table shows the process and results of the conducted literature searches:

Table 2: Literature searches: process and results

Search Set	**Process**	**Keywords**	**Results**
(1)Open Data and Education	Final search considering article title	"Open Data" AND school OR classroom OR "educational resource"	21
(2)Open Data and Gamification	Final search considering article title	"Open Data" AND Gamification OR "game based learning" OR games	16
(3)Open Data, Gamification and Education	Final search considering article title, abstract and keywords	"Open Data" AND school OR classroom OR "educational resource" AND gamification OR "game based learning" OR games	25
TOTAL			62

A literature review identified 62 potential studies. Initially, duplicated records were excluded, and inclusion criteria were considered in order to align the results with the research aim. Regarding standards of records, inclusion criteria led to excluding conference reviews and systematic reviews but considering primary studies. Although the systematic mapping review aimed at exploring connections between Open Data education and educational games, it was important to include studies where Open Data was directly involved. These final criteria led to the exclusion of 8 papers where Open Data was not directly related to the research aim presented in the study. For example, one of the excluded papers presented the learning effectiveness of gamification in a Massive Open Online Course (MOOC) about Open Data but not using Open Data (Castillo-Abdul et al., 2021).

Hereby, 28 studies including articles, conference papers and book chapters were considered for screening of abstracts and articles.

3. Results

The 28 reviewed articles were reviewed in-depth to analyse different approaches and perspectives in relation to three search sets, *Open Data and Education*, *Open Data and Gamification*, and *Open Data, Gamification and Education*. Different themes within the search sets were identified. Results created an overview of this novel field and helped to identify how Open Data education and educational games are related and contribute to the discussion of a game-based approach for Open Data in education. Results are shown in Table 3.

Table 3: Results, taking into consideration the search set.

Search set	Results	Themes	Records
Open Data and Education	11	Connecting classroom activities to real facts	(Radchenko & Sakoyan, 2014) (Selwyn et al., 2016)
		Empowering students to act with Open Data	(Berrio-Zapata & Santana, 2015) (Saddiqa et al., 2019a)
		Supporting technical Open Data skills in the classroom	(Badioze et al., 2021) (Chicaiza et al., 2017)(Piedra et al., 2015) (Saddiqa et al., 2019b) (Saddiqa et al., 2021b) (Watson, 2017) (Vallejo-Figueroa et al., 2018)
Open Data and Gamification	10	Building literacy and developing skills	(Suarez, 2015) (Stato et al., 2021) (Baker et al., 2017)
		Enhancing civic participation	(Handler & Ferrer Conill, 2016) (Wolff, 2017) (Bradley, 2009)
		Creating more realistic and appealing narratives	(Barros, 2019) (Edler, 2018) (Roa-Valverde, 2014) (Warren & Champion, 2014)
Open Data, Gamification, and Education	7	Extending teaching outside the classroom by collecting data in real time and local settings	(Dickinson et al., 2015) (Hsu et al., 2011) (Siriaray et al., 2018)
		Increasing engagement and motivation	(Chen et al., 2014) (Chiotaki & Karpouzis, 2020) (Da C. Júnior et al., 2015) (Vargianniti & Karpouzis, 2020)

3.1 Open Data and Education

Three themes were identified: (1) Connecting classroom activities to real facts (2) Empowering students to act with Open Data, and (3) Supporting technical Open Data skills in the classroom. This search set evidence the strong requirement of mechanisms or tools for integrating Open Data into educational designs developing and supporting skills and capacities to exploit Open Data.

1. Connecting classroom activities to real facts: Two articles explored the potentials and limitations of using Open Data in educational curriculums. Open Data was highlighted as a relevant educational resource when considering that it provides information about real facts (Radchenko & Sakoyan, 2014; Selwyn et al., 2016). Nevertheless, articles showed the need for further research on different technical, organisational and social barriers surrounding the use of Open Data in schools. For example, teachers and students lack skills and school administrators need guidelines. Articles suggested connecting to external developers to overcome current barriers.
2. Empowering students to act with Open Data: Articles elaborated on the relevance of Open Data, not just in providing information about the reality but in giving an input for transforming it. Saddiqa et al. (2019a) experimented on using local Open Data in the classroom, firstly to help students understand real facts, and secondly, to come up with ideas to improve their communities. Furthermore, Saddiqa et al. (2021b), and Berrio-Zapata & Santana (2015) elaborated on the importance of developing skills and competences beyond digital skills, such as the ability to understand local and global issues, and critical and scientific thinking to assess and select open datasets.
3. Supporting technical Open Data skills in the classroom: The literature showed a close relation between the capacities needed among students and teachers for managing Open Data, and possible tools to support them. Firstly, the articles focused on identifying open datasets for school subjects such as maths, science, and geography through mining techniques, interfaces and online communities (Chicaiza et al. 2017; Piedra et al. 2015; Vallejo-Figueroa et al. 2018; Saddiqa et al., 2021b). Secondly, the articles presented experiments with tools facilitating the use of Open Data in the classroom. Badioze et al. (2021) proposed PETS Robots called i-COMEL and the ThinkSpeak server, to collect and share data in a Solar System school class. Watson (2017) proposed helping students to create visualisations using the software TinkerPlots. Finally, Saddiqa et al. (2019b) focused on the development of an EAORE Open Data interface to help teachers and school administrators to achieve requirements of Danish public schools.

3.2 Open Data and Gamification

The different themes in this search set exemplify strengths in connecting Open Data together with games: (1) Building literacy and developing skills, (2) Enhancing civic participation, and (3) Creating more realistic and appealing narratives. Even though an educational aim was not always considered in these studies, Open Data and gamification implicitly supported educational purposes.

1. Building literacy and developing skills: The literature presented the use of games for building data literacy and decision making with Open Data. Suarez (2015) presented two games designed to develop Open Data and decision making skills for disaster management. Stato et al. (2021) worked on an online collaborative digital game to introduce players to Open Data, raise awareness and develop Open Data literacy among public servants, and Baker et al. (2017) elaborated on an Open Data game for developing decision-making skills.
2. Enhancing civic participation: The literature showed the potential use of Open Data games to enhance civic participation. Handler & Ferrer Conill (2016) analysed a case aimed at engaging journal readers. They showed that by using Open Data and game mechanisms, there was increased user autonomy, competence and contextual relatedness in readers. Moreover, Wolff (2017) presented a board game called DataScape to promote citizen engagement for smart cities. In DataScape, Open Data is initially used to help citizens understand their context, later the game dynamic motivated them to create, collect and share Open Data. Finally, Bradley (2009) demonstrated how to engage citizens in scientific experiments with a web-based game where players try to match molecules to various forms, creating collective knowledge and leveraging Open Data.
3. Creating more realistic and appealing narratives: Open Data helped to make entertainment game narratives more realistic and appealing (Barros, 2019; Edler, 2018; Roa-Valverde, 2014; Warren & Champion, 2014). Although games generated with Open Data did not have an explicit educational purpose, some of them facilitated learning, such as a game built with historical and spatial Open Data which implicitly led gamers to learn about cultural heritage (Warren & Champion, 2014).

3.3 Open Data, Gamification and Education

In this search set, articles presented studies connecting Open Data education and educational games. The two identified themes relate to the previous findings and scope in two areas. Firstly, the connection of classroom education to real facts and local context and secondly, the potential of increasing engagement and motivation in school education.

1. Extending teaching outside the classroom by collecting data in real time and local settings: Three studies have shown the use of games, through connecting school activities and learning tasks with real life settings and Open Data. Games enabled data collection in real time, which strengthened data literacy and skills among students (Dickinson et al., 2015; Hsu et al., 2011; Siriaray et al., 2018). For example, a game helped students to collect environmental data while walking to the school (Dickinson et al., 2015), while another game motivated students to navigate their city, collect data about their historical heritage and compare it to Open Data (Hsu et al., 2011).
2. Increasing engagement and motivation: Articles presented Open Data games used in the classroom to teach cultural aspects of their local context (Chen et al., 2014; Da C. Júnior et al., 2015) and environmental matters (Chiotaki & Karpouzis, 2020; Vargianniti & Karpouzis, 2020). Educational games using or collecting Open Data were used to increase engagement and motivation among students.

4. Discussion

A systematic mapping review was conducted to understand how the fields of *Open Data education* and *educational games* have been explored and to outline potentials for future development of Open Data gamified education. During the systematic mapping review, 28 articles were found and 8 themes were identified.

An Open Data Gamified Education Framework, presented in the following figure, highlights that a game-based approach for Open Data education can lead to authentic learning for real-world problem solving by addressing eight actions that connect the fields of Open Data Education and Educational Games: (1) Connecting classroom activities to real facts, (2) Empowering students to act with Open Data, (3) Supporting technical Open Data skills in the classroom, (4) Building literacy and developing skills, (5) Enhancing civic participation, (6) Creating more realistic and appealing narratives, (7) Extending teaching outside the classroom by collecting data in real time and local settings, and (8) Increasing engagement and motivation.

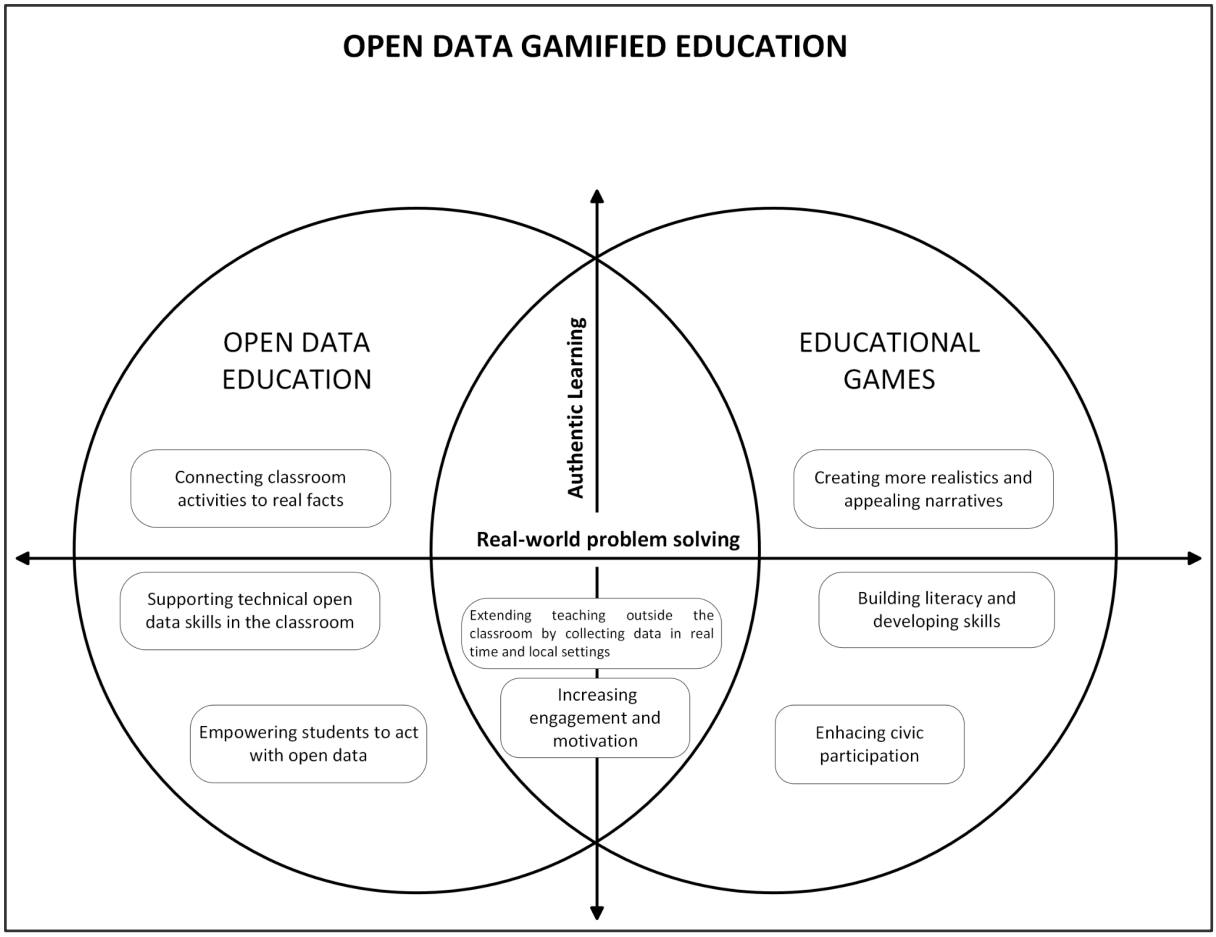


Figure 2: Open Data Gamified Education Framework

Education for real-world problem solving requires situating the learned knowledge in a different context building new meanings and constructing new worlds (Gee, 2006). An Open Data Gamified Education can create a new authentic context and realistic tasks based on Open Data. Acquiring a new language, skills and competences for collection, interpretation, and exploitation of Open Data in a local context can be achieved by using realistic and appealing narratives, and enhancing professional activities in a gamified environment. On the other hand, while technical skills might be supported by several gamified tools or mechanisms, educational games might lead to developing soft skills and competences to act with Open Data.

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Integrating the 4cs into Creating Games by Visual Programming and Project Based Learning

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Abstract: In recent years teaching methods and tools have changed due to the development of IT information technologies. The Teaching Learning Process is guided and supported by the use of technological and pedagogical drivers in a holistic way. This paper presents a teaching framework for the development of technologically supported learning environments, through the utilization of visual programming tools, such as Kodu and Scratch, proposed by the current and supplementary National Curriculum. Also, it proposes a framework of educational scenarios as a part of Games Based Learning practices within a Project Based Learning project that will be implemented during languages courses to K-6 students. Seventy-five Greek-speaking children of the fifth year of various primary schools of Athens participated in this study. The aim of the study was not only to examine how the creation of educational digital games with Kodu and Scratch can introduce primary school students to programming but also to investigate the developmental path of 21st century skills such as critical thinking, creativity, collaboration, communication (4Cs) and virtual/digital skills. A mixed method approach was adopted to explore the educational value of using these programming tools in the teaching-learning process. The research data was collected using observations, worksheets and questionnaires. The result of this study shows that the students were excited about the creation of their game by visual programming environments and project implementation, which was reflected by their active involvement in the learning process. The positive results of the research suggest that, in the proposed framework, the visual programming environments Kodu and Scratch can be dynamic learning tools during the teaching of language courses that support the development of students' expression and collaboration skills. Also, the above findings provide an approach for future teaching to K-6 students on developing narrative skills.

Keywords: ICT literacy, 21st century skills, Visual programming, Games Based Learning, Project Based Learning

1. Introduction

Apart from the vast social and technological changes that have been brought about by rapid technological advancements, it also affected education and training. Multicultural classrooms should be moving along with society, cultural trends, and scientific advancements. 21st century classrooms should no longer aim solely towards students' class performance but focus on utilizing school knowledge for the students to develop 21st-century learning skills like (4Cs) Communication, Creativity, Critical Thinking, Cooperation, and also digital literacy competencies like computational thinking (Wing, 2006; Hsu et al., 2018).

In Greece, Curriculum Guides in all subjects are becoming student-centered aiming to assist students to develop their learning skills on their own, as well as their research skills and their creative skills. In the essence of evolving, Programming and ICT courses are getting incorporated into elementary classes with the scope of promoting online learning but also to help students get used to participating in the knowledge-based society by growing their personal skills.

Research projects conducted by the educational society (Resnick et al.2009; Wilson et al., 2013; Chiu, 2020) globally have highlighted the significance of creating toolsets implementation, monitoring, and reviewing the use of visual programming environments for educational purposes. Current, Supplementary and New National Curriculum in ICT strongly recommend the integration of learning activities with the use of visual programming environments for fun activities and for creative expression at all primary school grades, in order to help students, develop problem-solving and computational thinking and to develop as creative thinkers (Resnick, 2007).

Kodu & Scratch, the visual programming environments which were used within our research, also being recommended by the Greek Curriculum (Curriculum in ICT, 2021) because they are powerful dynamic programming tools that can be used by teachers to introduce the students to programming courses in a fun way. They are easy to use and to understand (Chiu, 2020), they can be used to teach basic concepts of computer science (Resnick et al., 2009) and they provide an easy touch interface so that students build their own game only by manipulating graphical elements (Fowler et al., 2012). Moreover, they are also social as they can be linked to a community, where students can support one another and collaborate with one another (Resnick et al., 2009; Maloney et al., 2010).

The paper proposes a teaching framework of educational scenarios with the technical support of Kodu and Scratch and research highlights the way that these digital tools can create a dynamic learning environment during the teaching of language courses, while fostering knowledge and developing collaboration skills, communication, problem solving, decision making and critical thinking skills.

2. The teaching framework

2.1 Case studies-Plan and Objectives

The educational interventions were based on the following axes:
Developing Knowledge transfer skills by exploratory learning and discovery in authentic learning situations
Developing narrative skills, collaborative problem-solving skills and social skills
Relating the educational scenarios to different learning objects (language, sciences, history)
Using visual programming environments as cognitive tools to provide pedagogical guidelines (using a games-based construction approach)

2.2 Research participants-Lesson Overview

The educational interventions were held in different primary school of Athens during language courses to students of the 5th and 6th grade at years 2016, 2017 and 2018 as shown in the table below.

Table 1: Educational interventions

Year	Participants
2016	25 students (13 boys, 12 girls)
2017	25 students (12 boys, 13 girls)
2018	25 students (11 boys, 14 girls)

The students worked in groups of three and four members and they worked in the same pairs throughout the project. 25 of them were introduced to Kodu programming environment and the remaining 50 were introduced to Scratch programming environment. Most of the students had experience using online games. They were given a description of the project and its objectives and all of them were excited as the final product of the project would be their own digital game. Each educational intervention was a course of 12 weeks, as part of their language lessons.

2.3 Pedagogical Approach-Educational scenarios

The educational scenarios based on modern concepts of knowledge and learning and three main components were included as shown in Table 2.

Table 2: To design an educational scenario-three main components

Introductory Framework	Each scenario targets the teaching of the learning object.
Methodological framework	Each scenario targets the teaching of different learning objects, in an interdisciplinary perspective. Each scenario includes instructions for teachers, the theoretical framework and the activity sheets for students.
Principles of design and quality evaluation	Theoretical framework, the teaching subjects, teaching methods, teaching strategies, use of ICT as cognitive tools.

2.3.1 Theoretical framework

The theoretical framework of the scenarios focuses on contemporary teaching methods with modern pedagogical and teaching theories and on the use of technology in the constructivist approach (Papert, 1980; Bruner, 1986; Jonassen, 1994; Prensky, 2001; Van den Belt, 2003; Kafai, 2006).

2.3.2 The teaching subjects

The educational scenarios are implemented during language courses to students of the 5th and 6th grade. They target the teaching of the Greek language, investigate the developmental path of narrative skills and are also related to other learning objects (sciences, history) and to specific curriculum areas, in which the visual programming environments can be implemented as a cognitive tool (Komis et al., 2013).

2.3.3 Teaching methods

As contemporary pedagogical approaches and modern learning models require the active participation of the learners, the educational scenarios are based on the Cooperative learning (Meng, 2010; Konstantinidis et al., 2010; Fischer et al., 2013) and Project Based learning (Kolodziejski et.al., 2017; Chiu, 2020) as teaching methods. So, the teacher guides learning by implementing group activities and facilitating interactive experiences in the teaching and learning process.

2.3.4 Teaching strategies

The instructional design of the scenarios focuses on the development of the Jonassen Learning Model into the teaching process. The Jonassen Learning Model (Jonassen, 1994) is an instructional design model that is based on supporting the construction of knowledge and collaboration among students and with the teacher. Table 3 shows a breakdown of the lesson plan during the educational interventions.

2.3.5 Use of ICT as cognitive tools

The teaching and learning process requires active student participation and communication between students as they design the game world (objects and characters) and they program characters in order to create their own game. The programming environments Kodu and Scratch are used as cognitive tools.

The scenarios are implemented as a set of classroom activities. Table 3 shows a breakdown of the lesson plan during the educational interventions.

Table 3: Teaching and Learning Framework

Time	Teaching Subject	Teaching and Learning Activities
Weeks 1-3	Basic theme of the project Introduction to Kodu or Scratch as visual programming tools, Exploration and Practice	Teacher organizes the project groups and indicates the thematic range by brainstorming Students are given a demonstration of Kodu or Scratch environment characteristics. Worksheets are given to students for classroom work in the computer lab and instructions on how to write basic programs and how to create a basic game with one sprite and one background. Students work in pairs by using Kodu or Scratch command manipulatives.
Weeks 4-6	Narrative stories Scenario game for narrative production	Worksheets are given to students for classroom work in their class to write their picture stories. The stories are designed, illustrated and written by them, only by using Kodu characters or Scratch sprites (Figure1 & Figure 2). Students try to design their scenario game using a combination of storyboard with text.
Weeks 7-9	Building a simple game with a timer Game design using storyboards	Students are shown how to add a timer to their game. Students design a graphical storyboard that represents the sequence of scenes in their final scenario game.
Weeks 10-12	Creating the final game in Kodu or Scratch	Students are asked to complete the final programming project and to finish their digital game.



Figure 1: Worksheets – Scratch: narrative stories "The strange visitor"

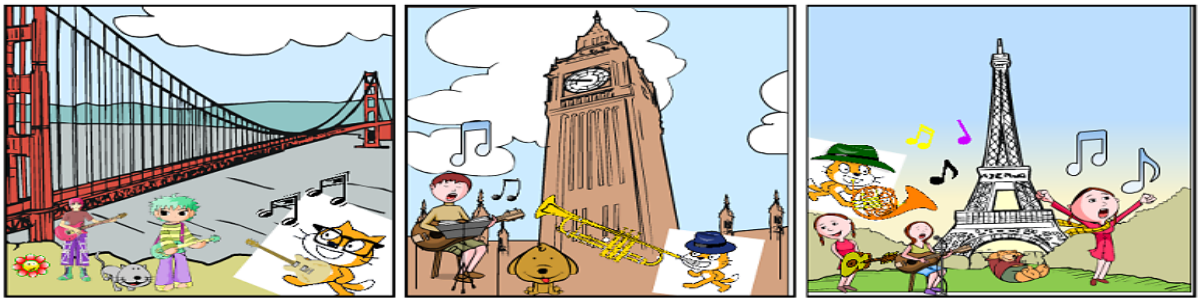


Figure 2: Worksheets – Scratch: narrative stories "Lyrics and notes"

2.4 The description of the games

2.4.1 Zante

The game's environment is based on the island of Zakynthos, Laganas Beach, where a Caretta turtle is struggling to locate a safe place for laying its eggs due to the summer vacation. A lot of tourists with vehicles, boats and tents are storming the beach trying to enjoy their vacation. All these crowds make it impossible for the turtle to overcome the obstacles, so it turns for help to the beach guard Kodu. Time is ticking away while the player is trying to guide Kodu towards the turtle without bumping into obstacles. For every obstacle Kodu hits, he loses energy that can deplete his life bar and lead to game over. Besides obstacles Kodu can reach red trees to refill his energy bar and gain extra points. Will Kodu manage to reach the turtle on time and win the game?

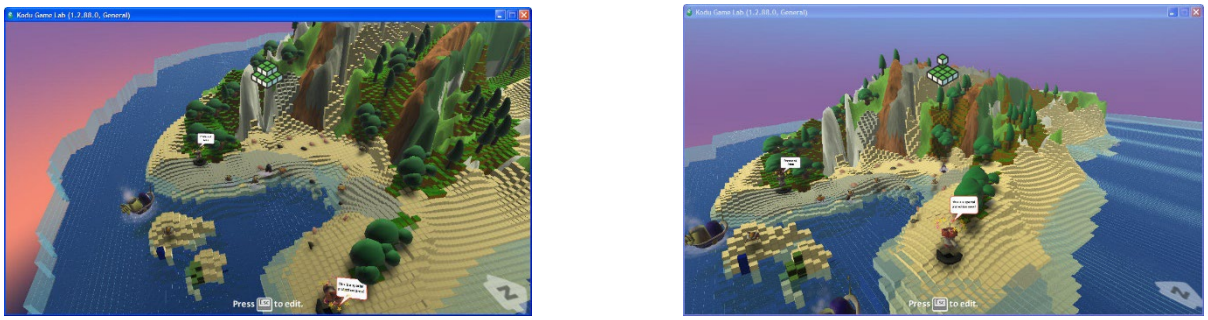


Figure 3: Snapshots: Digital game" Zante"

2.4.2 The treasure of Atlantis

Our hero decides to go on a quest to locate and claim the unspoken treasure lost on the mysterious Atlantis. His only hope is his skills and his fairy friend who accompanies him throughout his quest. Will he prove worthy?

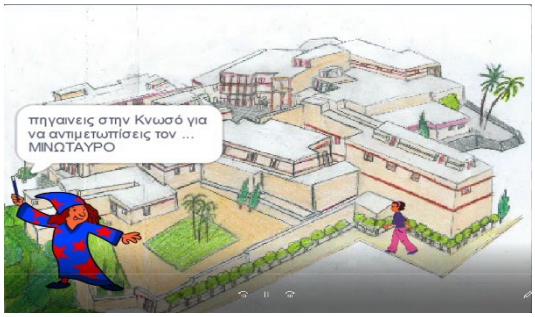
The game promotes problem-solving skills through puzzles while maintaining its adventure core. Basic principles are: 1) The player starts the game with ten (10) arrows and three (3) health bars shaped as hearts for life 2) The player must win battles against critters and creatures to advance to the next level, except for the sea world levels where he needs to avoid everything 3) The player can trade points for more arrows with a cost of 40pts. per arrow.

1st level: The player travels from Europe to Crete in Greece to the Fallen Kingdom of Knossos where he must find his way out of the famous Minotaur Labyrinth. He needs to find his way around the maze where he must face the mythical creature the Minotaur and defeat him. For every hit he takes from the Minotaur, one bar is taken off his health. If he touches the maze walls, he must start over. The reward for reaching the end of the maze and defeating the Minotaur is the first key and 150pts. If he can defeat the Minotaur using no more than five (5) arrows, he wins one hundred (100) bonus points.

2nd level: The player needs to swim across the Mediterranean Sea, while not having contact with any sea creatures. If he gets stung by the octopus, he gets stunned for five (5) seconds where he needs to make ten (10) clicks to break free or else he must start over. If he gets bitten by the crab, controls work backwards. If he gets eaten by the shark, he must start over. For every three (3) times he must start over it costs him a health bar. After reaching the end zone he is rewarded with the second key and fifty (50) points.

3rd level: The player reaches Atlantis where he faces the ocean god, Poseidon who challenges him to battle two (2) gryphons. These mythical creatures spit fireballs, which cost one health bar for every hit to the player. All it takes is five (5) arrows to kill one gryphon. If he succeeds, Poseidon acknowledges his worth and awards him with the third key.

4th level: The player manages to reach the final level, where the treasure chest is lying. He uses the three (3) keys to open the chest and … win the lost treasure of Atlantis!!!



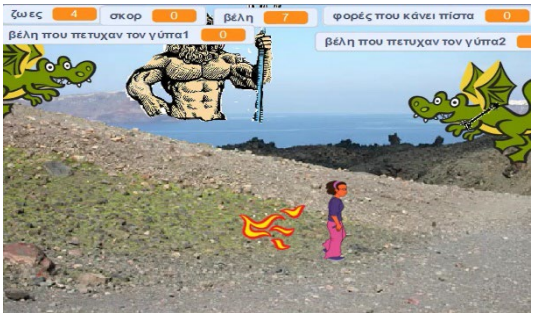


Figure 4: Snapshots: Digital game "The treasure of Atlantis "

2.4.3 Zeus Mission

Our hero undertakes a journey across the galaxy, aiming to reach planet Zeus with the scope of testing a theory of living conditions on the satellite Europa. He needs to go through the vast surface of Zeus, while overcoming several obstacles, battle alien creatures to reach a mythical diamond that can break through the ice surrounding the satellite Europa.

Will he make it? The game was inspired by renowned scientist Stephen Hawking's take on alien forms and human colonization on other planets. The game is a combination of action-adventure and puzzles while testing the player's knowledge.

For the first level, the player starts off outside the Great Red Spot of Planet Zeus. The player needs to enter and pass through the red spot to reach the surface of Planet Zeus. His health bar consists of three thousand (300) ice diamonds, divided into three (3) blocks. Passing through the Great Red Spot can't be described as an easy task, the player must overcome meteor showers and solve puzzles while the clock is ticking. Meteor hits can deduct fifteen (15%) to twenty (20%) percent of the player's health according to their size, not solving a puzzle in time will also cost him ten (10%) percent of his health. For every correct answer he is awarded with thirty (30) ice diamonds, while for every wrong one his health bar will be deducted by thirty (30%) percent.

After completing the first level, the player advances to the second level where he starts from the surface of Planet Zeus and tries to reach its core to claim the mythic diamond. The player's health is determined by his performance on the previous level plus one hundred (100) ice diamonds that are handed to him as a bonus. The player needs to overcome several obstacles, correctly answer questions, solve puzzles, and battle alien monsters to get his hands around that diamond. The level starts off with theoretical questions regarding the Highway Code and then the player needs to go through a practical exam. If the player complies with the Highway Code rules,

he earns twenty (20) ice diamonds. If not, this health bar is deducted by fifty (50%) percent. After leaving the city of Zeus, the player comes across four (4) alien creatures which must defeat. One hit is enough to defeat the aliens except the super alien which will need three hits. For every alien he defeats he is awarded forty (40) ice diamonds and for every blow he takes from the aliens his health bar is deducted by five (5%) percent. The diamond is essential for advancing to the next level and completing the game. The player must have at least five thousand (500) ice diamonds at his disposal to unlock the diamond, if not he needs to start over.

For the third and final level, the player's health is determined by his performance on the previous level. The player needs to solve a last puzzle by answering several questions correctly and then he must break the ice of satellite Europa with the use of the diamond. If he succeeds, he reaches the game's finishing line.

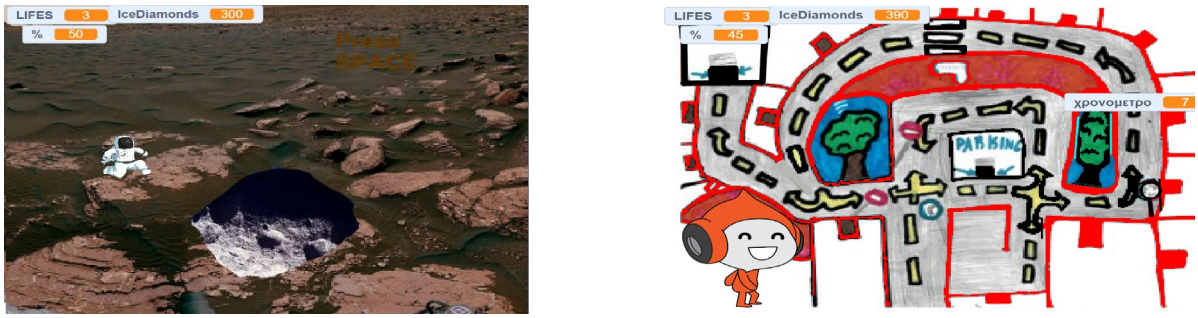


Figure 5: Snapshots: Digital game "Zeus mission"

3. Evaluating the educational interventions

In the context of this research, issues concerning the design and the implementation of technology supported learning environments through the use of visual programming tools such as Kodu and Scratch. Furthermore, it examines the way that the programming environments through game-based construction can be the best used as teaching and cognitive tools as well as their contribution to the development of learning and social skills. Analysis results revealed that collaboration between students worked almost flawlessly and when educational gaming is used in the learning process to teach ideas in engaging and interactive ways it causes positive reactions to students. Also, the description of a scenario game serves as an excellent text for languages courses emphasizing multiple approaches to the study of narrative.

3.1 Observations

The results of the evaluation process derived from direct observation during the educational interventions as the teacher-researcher investigates the contribution of the visual programming tools in the teaching-learning process through authentic teaching examples. The researchers observed especially the following topics: what was difficult, what was too easy or boring for the students while approaching the programming environments during the implementation of their games (formative evaluation).

According to our survey, all participating students found the experience highly satisfying. They were excited by programming with Kodu and Scratch and by working collaboratively, using programming to express their ideas. Most of them engaged with the game at the school lab without going out for a break and they continued their work at home. All of them were motivated by designing their scenario game and they developed meaningful storyboards.

3.2 Questionnaires

The results of the evaluation process derived also from the questionnaires completed by the 75 participants after the implementation of their digital games.

The teacher researcher and the other two researchers developed the questionnaires using questions from a teaching framework in Kodu Curriculum which was designed for a Microsoft DigiGirlz Technology camp (Kodu Game Lab: Kodu Teacher Guide), adapted the questions for K-6 students and added questions based on the goals of the research. The questionnaire of each programming environment consisted of 21 closed questions to be answered on a five – point Likert scale ranging from *strongly disagree* to *strongly agree*. The statements in the questionnaires were divided into three categories: Attitudes towards computers and programming, attitudes

towards the use of visual programming environments and attitudes towards the use of educational games in the learning process. Table 4 presents some items from the three different categories.

Table 4: Questionnaire categories

Attitudes towards computers and programming
I spend more than 2 hours each day playing video games
I know a lot about computer programming and visual programming languages
If my school offered a computer science class next year, I would take it
Attitudes towards the use of visual programming environments
Playing games in Kodu or Scratch is easy
Creating games in Kodu or Scratch is easy
My team worked well as a group during the creation of our game in Kodu or Scratch
Attitudes towards the use of educational games in the learning process
I decided to try out Kodu or Scratch because I wanted to create my own game
I used to study at home by using Kodu or Scratch command manipulatives, in order to finish my game
I recommend the existence of digital games in other lessons too

Almost all of participating students found the visual programming tools useful for them with a simple visual interface that allows them to create their own digital game or their animation (95% positive review). 90% of the students indicated that they enjoyed working together on the design of their games and 85% of them particularly liked the fact that they can share their digital games online and can introduce the game to their friends.

Finally, 84% of the students demonstrated a positive attitude toward the use of the educational games by the visual programming tools in the learning process, as shown in Table 5.

Table 5: Attitudes towards the use of educational games in the learning process

	Frequency	Precent	Valid Precent	Cumulative precent
negative	3	4,0	4,0	4,0
neutral	9	12,0	12,0	16,0
positive	63	84,0	84,0	100,0
Total	75	100,0	100,0	

4. Conclusions

The aim of this paper was to summarize the effectiveness of educational scenarios as a part of Games Based Learning among primary school children. The intersectional educational scenarios were designed and implemented to develop narrative skills during language courses, in the context of project method application in educational practice.

Meanwhile it managed to enhance the participants' active participation and creative expressions since the scenario's theme/topic are based on their personal interests and real-life based applications. In addition, they grow the participants' digital skills, imagination and creative thinking through the process of developing their own digital game. As Resnick (2017) stated: by creating opportunities for children and teens to work on projects, based on their passions, in collaboration with peers, in a playful spirit, we will be able to prepare them for a world where creative thinking is more important than ever before.

Kodu and Scratch Visual Basic Programming Environments were used for the teaching activities of the educational scenarios along with the development of project method. The outcome of the presented research contributes to the existing findings of similar research that aim to successfully integrate this methodology of developing digital applications or games with the use of Visual Basic Programming Environments during the introductory Programming courses and for developing social and other skills like thinking creatively and working collaboratively (Resnick et al., 2009).

Research findings have proven that the utilization of these programming environments for educational purposes has positive effects on the development of several skills like cooperation, communication, problem solving along with social interacting. The features of the Programming Environments seem to bring out an amusing effect for the participants, while the ability to create their own game was really intriguing for them.

The students were given the chance to realize their ideas-scenarios into digital worlds, heroes, and objects during the game-based learning activities. The outcome was quite impressive, they managed to develop games with an exceptional plot, clear instructions, and goals. Also, the researchers observed that by not having syntax complexity, Scratch and Kodu allowed beginner programmers to solve complex problems quickly.

During the development process, all the participants were constantly interacting and cooperating in groups to produce the best results. After completion they seemed eager to share their game not only with one another, but also on the program development forums.

To conclude, regardless of the learning activities or the teacher's capabilities, for the development of learning skills but also for achieving higher learning goals, teachers should embrace pedagogy theory and the value of utilizing Logo, the first child friendly programming language, if used properly.

They should really try to promote the creative side of programming, since any programming activity is an essential tool for all learning activities in multicultural classes of the 21st century.

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Board Game: An Effective Way for Novice Trainees to Learn Incident Command System

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Abstract: The incident command system (ICS) is widely used in disaster management, but it is hard for novice learners to apply what they learn in actual practice. Considering these aspects, we developed a board game for novice learners to learn ICS and conducted a study to evaluate the effectiveness of the board game method compared with that of traditional lectures. Two sessions of ICS training were conducted using only board games and lectures for each session. In the board game session, the participants played the board game for 1.5 hours without receiving any teaching. The game participants played as disaster response teams based on ICS principles. In the lecture session, a didactic lecture on ICS concepts and their applications in disaster medical assistance team (DMAT) work was taught for 1.5 hours by a disaster medicine expert. Before and after each session, a test comprising 20 multiple-choice questions (5 points for each question) was conducted. In the test, participants were evaluated on how to apply the ICS principle to DMAT work. Participants who had not previously received any disaster medicine education were defined as novice learners and were included to compare the learning effects of the two methods. A paired t-test was used to compare the results within each group, and an analysis of variance (ANOVA) was used to compare the results between the two groups. The study included 17 participants in the board game group and 25 participants in the lecture group. The mean test score was significantly higher after the game and the lecture (pre-game score = 56 versus post-game score = 75, p-value = .001; pre-lecture score = 58 versus post-lecture score = 74, p-value = .002). No significant difference was found in the score improvement between the two groups (p-value = .6). Hence, we can concluded that learning ICS through board games was as effective as using the traditional lecture method for novice disaster medicine trainees. The board game is an useful tool of disaster medicine education.

Keywords: Disaster medicine, board game, incident command system, disaster medical assistance team

1. Introduction

Disasters occur frequently in Taiwan, which can cause damage. When it happens, a disaster medical assistance team (DMAT) is sent to the disaster scene to provide healthcare. A DMAT usually comprises a variety of healthcare professionals with different backgrounds and specialties, and a command system is needed to organise the team. In Taiwan, the incident command system (ICS) is commonly used to organise the DMAT. The ICS, which is a standard element of incident management utilised by emergency management and response personnel as a tool to coordinate equipment, facilities, personnel and other resources during an incident, has proven to be a robust system and has been adopted by public health agencies (Granillo et al., 2010). This command system contains four sections and command staff. Each section can be further divided into several branches or units (Figure 1). The tasks of each command staff, section, branch and unit are specific and different, but all sections and staff need to collaborate to complete the mission. Despite being commonly used in emergency management and taught in disaster medicine education, ICS is hard for a DMAT novice to learn. Not only do DMAT members need to understand the ICS concept, but they also need to be able to use the ICS and work with others. Therefore, ICS education has become a fundamental part of DMAT training.

Traditionally, the use of the ICS has been taught through lectures and practice and evaluated via disaster exercises. However, traditional didactic teaching has been linked to low knowledge retention rates and poor participant engagement (Bangalee et al., 2021). Research has suggested that while disaster medicine training may require replicating a learning environment to simulate a disaster scene, true disaster cannot be fully achieved in the real world (Knight et al., 2010). However, learning by game-playing has been deemed to have great potential compared to traditional learning (Moradian and Mehraein, 2019), proven to be an effective method for engaging students (Kang et al., 2013) and shown to create a risk-free environment for decision-making and problem-solving learning (Karbownik et al., 2016). Considering that board games have been used successfully as educational tools in several healthcare settings (Yoon et al., 2014), we designed a board game for DMAT trainees to learn ICS. By playing the game, trainees can learn how ICS works and become more skilled as they play (Knight et al., 2010).

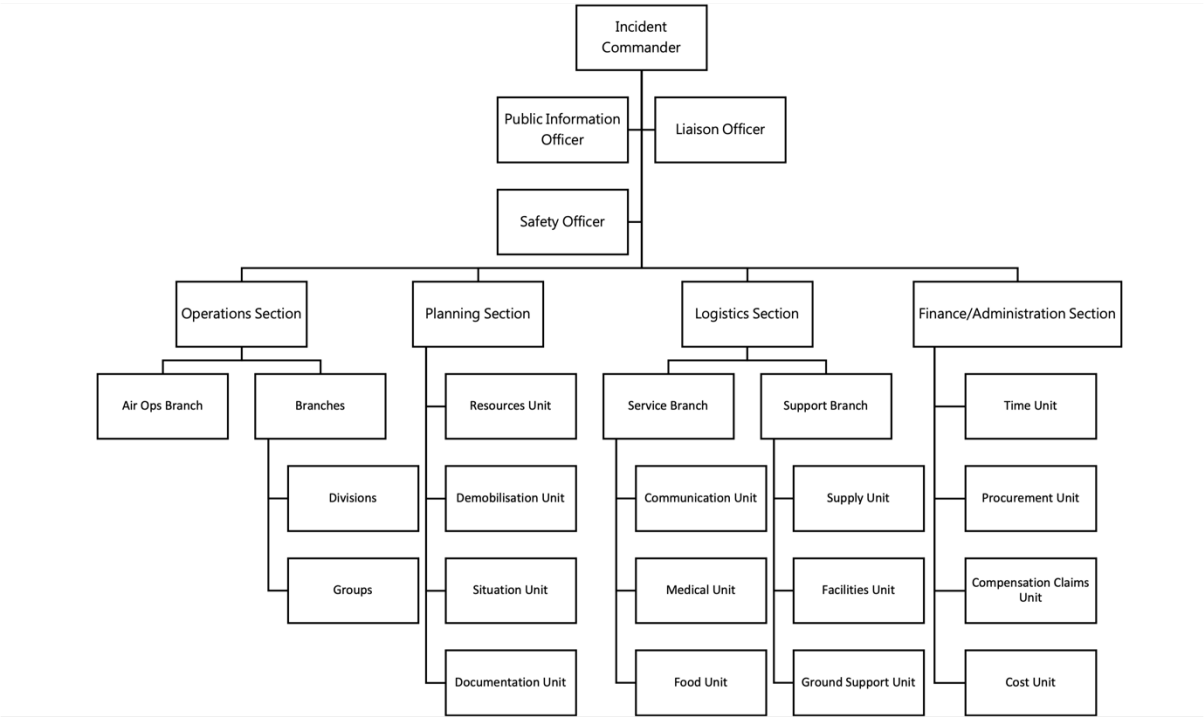


Figure 1: ICS containing command staffs, sections, branches and units.

By contrast, other researchers have claimed that there is no strong evidence for the use of educational games as learning tools (Karbownik et al., 2016) and that current scientific data neither confirm nor refute the utility of educational games as a teaching strategy (Karbownik et al., 2016; Akl et al., 2013; Akl et al., 2010) compared with traditional methods. Some research has even indicated that traditional lectures are more effective in increasing student knowledge compared to learning by a board game alone (Charlier and De Fraine, 2013), while other research has shown that games are used merely as supplemental teaching tools in education (Bochennek et al., 2007) but not as primary tools. Currently, there has been no study of the effectiveness of learning ICS through games. Therefore, we aim to determine the pure effectiveness of games for ICS training, especially for trainees who have not received any previous ICS or disaster medicine education. To achieve this goal, we conducted a study to compare the effectiveness of ICS learning by game playing with that by traditional lectures.

2. Methods

2.1.1 Game design

We developed a board game to teach ICS. We created a board game with a simulated town (Figure 2) containing several buildings with different numbers of residents in each building. An earthquake played by an instructor struck the town. The game was turn-based, and in each run, the instructor enacted a variety of disasters, such as building damage, floods, mudslides, fire, communication interruptions and chemical spills. Each turn represented 12 hours in that game, and the weather and day–night status changed each time, causing further impacts on the town or participants. As some specific impacts also had knock-on effects, such as impacts on a thermal power station leading to power outages in the town, the players needed to be aware of such impacts in their disaster response.

The game participants played as disaster response teams, with each team comprising 15 to 25 participants. The roles of this team were set based on a simplified ICS (Figure 3). Therefore, each participant took on a certain role in the ICS structure and performed the task defined by the role. The participants were required to save the lives of town residents, repair the damages and protect the team from harm. The operations section aimed to save the lives of town residents and remove impacts, such as fire, flood or chemical spills. Each branch of the operations section had different abilities to perform specific tasks. The planning section needed to collect information, analyse the situation and provide suggestions to other team members for decision making. The logistics section needed to buy supplies to improve the capability of disaster response. A disaster response fund, controlled by the finance section, was given to the team to improve response capacity, gather information and buy supplies. The command staff needed to protect team members, reach outside resources, deliver public

information, command and coordinate each section, and make the final decision of response in each run. Each run comprised only 10 moves, so the participants needed to work together to consider what moves should be made based on limited information and funds and to accomplish the task (Figure 4).

The participants were briefed on the game rules for 10 minutes and the rules were posted on the wall. The game lasted for one and a half hours. The participants completed six to eight runs during the game period, depending on their response speed. At the end of the game, the number of lives taken by the disaster and saved by the participants was scored as the final result for each team.



Figure 2: The game board showing a simulated town. (Apt. = Apartment)

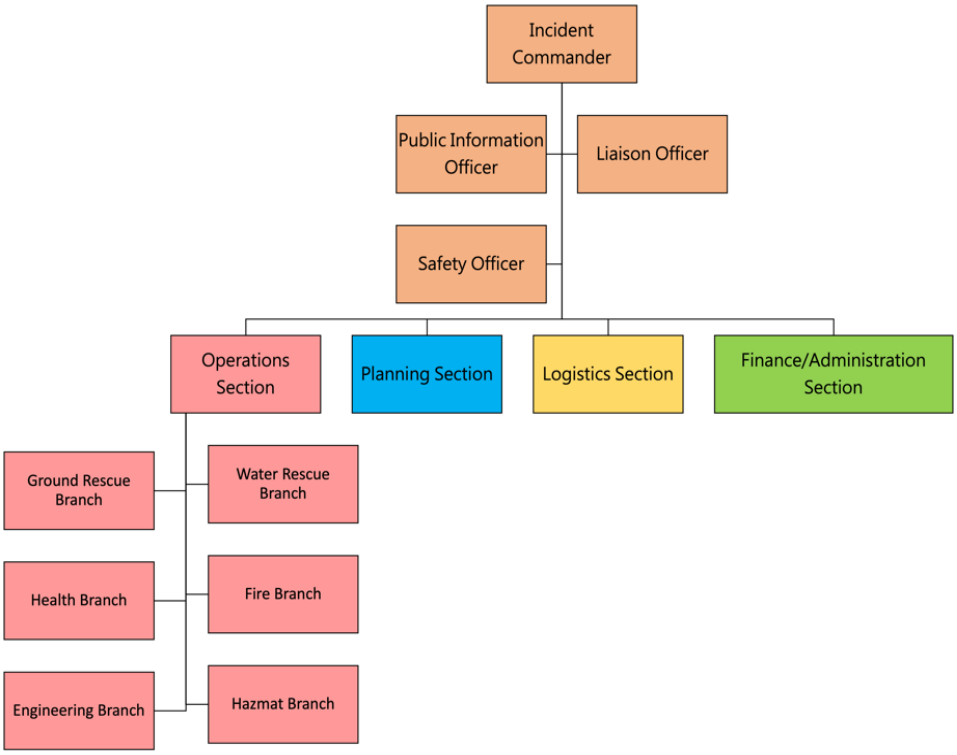


Figure 3: Simplified ICS used in our board game.



Figure 4: Game participants in different sections worked together to accomplish the task.

2.1.2 Study design

The DMAT training was conducted in 2020 and 2021. In the 2020 course, the ICS board game was used in the training. In 2021, a lecture on ICS was taught via a DMAT training course by a disaster medicine expert on the content of ICS concepts and their applications in DMAT work. Both courses contained an educational intervention through lectures and game methods for 90 minutes.

Before the game or lecture, a demographic questionnaire was used to collect relevant information, including age, gender, occupation and previous experience with disaster medicine training. A test was designed based on previous DMAT experience using ICS. A disaster scenario that required a DMAT was set in the test, and the questions asked participants about how to apply ICS to DMAT work. The test included 20 multiple-choice

questions. A correct answer was given five points, and an incorrect answer received zero points. All trainees who attended the DMAT ICS training were invited to complete the test before the training to determine their prior knowledge. The same test was used immediately after the game or lecture to evaluate the effectiveness of the training session. Because of the reason for the research, the debriefing and discussion of the game were conducted after the post-test. The test was conducted through Google Forms. Different Google Forms were used before and after the lecture and game-playing. The participants cannot change their answer after the lecture and game-playing. Novice learners were defined as trainees without previous experience in disaster medicine training. Novice learners who completed the questionnaire, pre-test and post-test were included in the study.

2.1.3 Analysis

Within each group, the differences between the pre- and post-test scores were analysed using a paired *t*-test. An analysis of variance (ANOVA) was used to compare the results between the two groups. The difference was considered to be statistically significant at a level of $p < .05$ (two-tailed).

2.1.4 Ethical statement

The study protocol was approved by the institutional review board of the National Taiwan University Hospital. Oral informed consent was obtained from all subjects prior to enrolment. To protect the privacy of the participants, all questionnaires were filled out anonymously and the researchers kept all data confidential. The survey and test results were used only for the study.

3. Results

Of the 75 trainees who attended the DMAT training in 2020, 17 were novice learners and were included in the study as the board-game group. In 2021, 85 trainees attended the DMAT training. Of these, 25 were novice learners who were included in the study as the lecture group. All novice learners in both groups completed the questionnaire, pre-test and post-test. The majority of the participants were nurses. Table 1 shows the demographic characteristics of both groups.

Table 1: Demographic characteristics of the participants

Variable	**Board-game group (N = 17)**	**Lecture group (N = 25)**
Age		
<30	2	11
30–50	10	14
>50	5	1
Gender		
Female	12	20
Male	5	5
Occupation		
Medical doctor	2	1
Nurse	11	19
Other	4	5

Table 2 shows the scores for the pre- and post-tests. The mean pre-test scores were 56 and 58 in the board-game group and lecture group, respectively. The mean post-test scores were 75 and 74 in the board-game group and lecture group, respectively. Therefore, the pre- and post-test scores for both groups were similar and the scores improved significantly in both groups ($p < .05$). There was no significant difference between the board-game group and the lecture group in score improvement ($p = .6$).

Table 2: Mean scores of the pre- and post-Test

	Board-game group	Lecture group
Pre-test score	56	58
Post-test score	75	74
P-value	.001	.002

4. Discussion

The DMAT can be employed to provide medical care after all kinds of disasters, ranging from terrorism to natural disasters. Regardless of disaster type, a robust command structure is essential for successful DMAT work. However, due to the rarity of disasters and deployment, DMAT members may be unfamiliar with the command

structure used in disaster management (Barnett et al., 2005). Healthcare providers who work at different organisations have their own command structures during ordinary times. However, in DMAT work, they need to work with unfamiliar people under an unfamiliar structure. Therefore, it is vital for DMAT members to have training opportunities to learn and practice the command structure. Previous reports have confirmed the necessity of command structure education based on previous disaster management experiences (Barnett et al., 2005; Crichton and Flin, 2001).

Traditionally, education in disaster medicine has been taught using lectures and/or disaster exercises (Hu, Liu and Li, 2020). However, passive education, such as classical formal lectures, may have some disadvantages in transferring knowledge (Karbownik et al., 2016). Although lectures require less funding and fewer teaching resources, they are often less stimulating and more abstract, which may jeopardise learners' intellectual interest in the subject and might extinguish learners' desire to pursue their study in the targeted subject matter (Hu, Liu and Li, 2020; Beigzadeh and Rahimi, 2015). Furthermore, traditional lectures may not reflect the levels of complexity of practical applications or real-life situations, such as disasters (Bochennek et al., 2007). Disaster exercises are another common method of training and education for disaster medicine, especially for incident command (Crichton and Flin, 2001). Unlike lectures, disaster exercises may be a good method to help learners gain knowledge or skills. Tabletop exercises have been used to teach ICS effectively and at a low cost (Sena et al., 2021); however, learners may not feel the reality of the disaster or lack engagement in the disaster response in this type of exercise (Knight et al., 2010). By contrast, full-scale exercises can create an environment close to disaster but may require considerable funding and a large amount of educational resources (Hu, Liu and Li, 2020). It is also difficult for learners to understand the concept of ICS while participating in a full-scale exercise because they may not be able to see the whole picture in this type of exercise.

The aim of education is to shape human behaviour (Moradian and Mehraein, 2019), which in our case refers to understanding and applying ICS. Behavioural changes may result from a change in perceptions and experiences or both simultaneously (Kang et al., 2013). The education method is an important factor in internalising knowledge and directing it towards correct behaviour (Moradian and Mehraein, 2019). Therefore, appropriate educational approaches should be chosen to obtain the most efficient results (Kang et al., 2013). To shift learners from being recipients of passive knowledge to becoming active and motivated participants, an educational approach that is different from traditional methods should be chosen. The approach should require participation, develop interaction between learners, promote the integration and application of knowledge, and generate motivation, which are basic features of games (Achatz et al., 2020). As previous literature has previously suggested games as an education tool with promising results (Yoon et al., 2014; Kang et al., 2013; Moradian and Mehraein, 2019), and the nature of ICS in the application of disaster management requires a flexible core command mechanism to drive incident response (Kohn et al., 2010), we used games as the method for ICS education.

In our investigation, the lecture group participants were taught about ICS concepts and their applications in DMAT work, while the board-game group participants learned through applying the ICS concepts in a game without receiving a lecture. This may be a vital factor in the effect of our ICS board game. Bloom's Taxonomy, a hierarchical model used for classification of educational learning objectives, describes different levels of learning, from basic to complex. There are 6 levels: knowledge, comprehension, application, analysis, synthesis, and evaluation (Figure 5). Each level builds on the previous level from basic recognition of information to resolving controversies. The application represents the third level of Bloom's taxonomy, which typically requires previous knowledge (Chittum et al., 1996). However, in our study, the knowledge and comprehension levels of Bloom's taxonomy may be completed through the direct application of ICS concepts during the game play. Therefore, participants learned how to apply ICS to disaster rescue in the game and can further apply it to DMAT work.

The game mechanism is also a key factor in transferring knowledge to players (Bochennek et al., 2007). The ICS is a command structure, and its value lies in its use for incident management. An important part of learning ICS is how to apply it to a team or task. Unlike in other educational games where questioning and answering are used, the participants in our game were required to play certain roles and apply what we wanted them to learn. For example, one of the game participants fulfilled the role of incident commander and led the team in a game that simulated a disaster scene. This role-playing mechanism likely contributed to the learning effect of our game (Barnett et al., 2005).

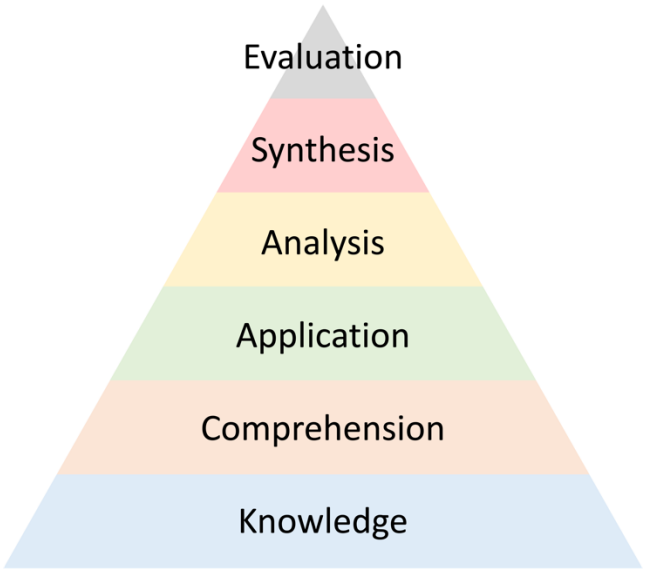


Figure 5: Six levels of Bloom's Taxonomy.

A unique feature of the ICS application is that it requires multiple participants to use it, which suits the concept of teamwork. Compared with traditional lectures, board games are a useful tool for promoting teamwork (Yoon et al., 2014). Through teamwork in the game, participants can gain knowledge and promote collaboration (Bangalee et al., 2021), especially in simulation games with reality-based scenarios and action-oriented activities (Vlachopoulos et al., 2017). Teamwork is vital to DMAT operations because team members also need to work together in teams. Additionally, DMAT trainees may actually form a team in the future if a disaster occurs (Bangalee et al., 2021). Educational games that involve teams can promote teamwork and collaboration and simulate real work problems (Akl et al., 2013).

To ensure that DMAT members are ready to work, both novice and experienced members need to attend regular training. Using board games as an educational intervention, novice learners can gain their knowledge from other experienced DMAT members while playing the game as a team (Bangalee et al., 2021). Interaction and cooperation with other game participants may promote active learning (Vlachopoulos et al., 2017; Bochennek et al., 2007). This interaction of game-based learning can engage learners more effectively than lectures (Hu, Liu and Li, 2020).

Another commonly used educational tool for disaster training is disaster exercises. Compared with the reality, fidelity and validity that disaster exercises represent, educational games can provide learners with a positive, pleasant and relaxing learning and practicing environment (Whittam and Chow, 2017; Ma et al., 2021; Beigzadeh and Rahimi, 2015). In this risk-free environment, decision-making and problem-solving learning can be achieved (Karbownik et al., 2016; Charlier and De Fraine, 2013). Moreover, as there are different sections and branches in ICS, the participants can assume one of these roles while learning and practicing ICS. The environment created by our board game included 15 to 25 participants in one room, which allowed participants to see what other roles were doing. In this way, the game participants can learn the whole picture of the ICS more thoroughly than if they were to learn during a full-scale disaster exercise.

Because disasters do not usually happen frequently, many learners may lose their skills or knowledge due to a lack of exposure or practice (Sena et al., 2021). Therefore, disaster training should be repeated at regular intervals to prepare responders for unexpected events. However, while traditional lectures and disaster exercises require instructors, facilitators and/or evaluators, educational games require minimal or even no direction from the facilitator (Sena et al., 2021). Learners can repeat the games many times, allowing players to learn from the experience through the game mechanism of scoring (Charlier and De Fraine, 2013).

Some studies have applied games for education on disasters with good results, but most of them have used digital games (Moradian and Mehraein, 2019). We chose board games to teach ICS for several reasons. First, the development and application of digital games require a high cost that is burdensome for many DMATs (Ma et al., 2021). Second, board games like ours can be easily adapted without the need for programming knowledge

(Charlier and De Fraine, 2013). Finally, the success of disaster management depends on responders' cooperation and communication. The board game used in our study enabled up to 25 participants the chance to cooperate and communicate with each other face-to-face, instead of with computer monitors. Such a setup mirrors a real disaster response, what is used in ICS and what we wanted our participants to learn.

5. Limitations

Our study has several limitations. First, our study design was a cohort study instead of a randomised control study, and the age distribution of both groups was different. The sample of the participants was not random, which may have caused some degree of selection bias.

Second, we did not evaluate the effectiveness of long-term knowledge retention. Our study results showed no difference between the lecture and board-game groups based on the tests that were conducted immediately after the lecture and game. However, some research has reported that games did not significantly surpass lecture-based education in the immediate cognitive post-test but exerted its effect on knowledge retention (Karbownik et al., 2016; Hu, Liu and Li, 2020). Longer and repeated follow-ups may reveal different outcomes, and future research should consider the long-term knowledge, skills and affective levels of learners.

Third, there was no evaluation of learners' subjective feeling. The fun of games makes them enjoyable and encourages knowledge acquisition and retention (Hu, Liu and Li, 2020). However, we did not investigate whether the game participants found it interesting, what they thought were the possible knowledge-improving factors or whether they had any suggestions to improve the game. Future studies could explore these subjective factors to identify the advantages and disadvantages of game-based learning.

As in many studies, the board game in our study was conducted by the instructor. Although the instructor did not give a lecture during the game, there was no evaluation of the learning effect in the environment without the instructor. By acting in a facilitating and supporting role, instructors can foster learning, particularly by discussing new information (Vlachopoulos et al., 2017). The pure effectiveness of educational games should be evaluated in the absence of a teacher or instructor.

6. Conclusion

This ICS game is the first board game in the field of ICS education. Comparing the learning results, we found that the board-game group's application of ICS improved immediately after the game. Our study thus suggests that a board game based on ICS concepts is an effective pedagogical method and can be used alone as a primary tool for novice trainees. The ICS board game can also serve as an initial tool for people who want to learn about ICS. Using board games in disaster medicine education is highly promising and should be further explored in other areas of disaster medicine.

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A Serious Game on Shaping Employee Behavior for the Digital Transformation: Design Considerations for a Serious Game on using HR to Shape Employee Behavior for the Digital Transformation

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Abstract: Organizations increasingly embrace the digital transformation (DT): organizational change shaped by the widespread diffusion of technology. This results in specific demands in terms of employee behavior. Organizations need to adapt to technology-driven work methods and proactively set out to reap the benefits of new technology. Shaping employee behavior conjures a significant challenge for organizations. While aligned HR configurations shape employee behavior, the number of interrelated HR practices to select from is vast. Currently, no tool aids professionals with the design of an HR configuration that shapes DT behaviors. DITInLine is a serious game that captures this challenge; it invites professionals to design an HR configuration that shapes the DT behaviors of employees. Departing from the state of the art HRM literature, it presents professionals with a set of granularly defined HR practices that can combinedly be implemented during the game. The game provides feedback on the impact of their decisions. Professionals are challenged to combine those HR practices into a strategy-aligned HR configuration that shapes the employee behaviors most effectively. After each round, feedback on the HR configuration design is provided to the players. By providing an abstract representation of the HR and DT challenges that organizations face, DITInLine constitutes a valuable tool for professionals tasked with designing aligned HR configurations. DITInLine forces managers to be explicit about their HR decisions. It provides a risk-free environment for them to experiment with HR practices and gauge the effects of their decisions, potentially enabling learning. From a research perspective, the HR choices of these professionals are made explicit. It enables studying HR decisions. Furthermore, the serious game introduces a promising level of detail, providing a falsifiable theoretical framework on the impact of HR for DT.

Keywords: Serious Game, HR, Human Resources, Employee Behavior Change, Digital Transformation

1. Introduction

The technologies that make up the digital transformation (DT) seem to bear undisputed potential. I.e., combining technologies such as smart sensors, data analytics and co-bots can not only increase efficiency and effectiveness, it potentially alters the value proposition that an organization upholds. Specific examples include reduced waiting time and improvement of performance using smart logistics and using algorithms to increase maintenance efficiency (Woschank et al., 2021). However, as organizations seem increasingly eager to embrace the DT, it becomes evident that technology is only one part of the puzzle that organizations must solve to truly reap the benefits of the DT (Vial, 2019). Accordingly, the DT involves structural and organizational changes to overcome barriers that affect the process with which these technologies create opportunities for the organization. One particular challenge organizations face is how to steer employee behaviors towards what is needed to capture the benefits of the DT. Human resource management (HRM) is the domain that addresses shaping the behavior of employees. Despite that a vast body of knowledge illustrates that HRM affects (employee) performance (Jiang, Lepak, Hu, & Baer, 2012; Schuler & Jackson, 1987), the intricacies of how HRM does this, and in turn how organizations can design their HRM, lacks specific insights that professionals can readily apply in practice.

The goal of this paper is to present the design considerations and initial prototype of DITInLine. This serious game challenges professionals to select and detail a set of human resource (HR) practices (HR configuration) that shapes the employee behaviors needed for the DT. DITInLine is a new addition to a set of serious games that address and capture the challenge of strategy alignment (Collou & Bruinsma, 2017; Collou, Bruinsma & Iacob, 2021) specified for this particular HR and DT challenge. The paper is structured as follows, the concept of strategic alignment and why serious games are a valuable tool to address this challenge is presented first. Subsequently, the design and functionalities of DITInline are presented, including the specific employee behaviors needed for the DT. Finally, the implications of DITInLine and future work are discussed in the conclusions.

2. Strategy Alignment & Serious Games

Literature on strategy alignment stretches several decades and multiple domains. Examples include information technology (IT) and strategy alignment (Cumps, Viaene, Dedene & Vandenbulcke 2006), HRM and strategy alignment (Gratton & Truss, 2003), and project management and strategy alignment (Alsudiri, Al-Karaghouli, & Eldabi, 2013). Results seem promising In IT, for example, research has shown that alignment between business and ICT has a positive effect on performance (Cumps, Viaene, Dedene & Vandenbulcke 2006).

Hence, organizations ought to 'align' their domain specific practices to the organizational strategy in order for those practices to contribute to strategic goals. While the strategy is a multifaceted concept, attaining domain to strategy alignment is a complex challenge for five specific reasons.

First, specifying the organizational strategy is a challenge. In small and medium sized enterprises a formalized strategy is rare (Knol, 2013) which makes it hard to specify what it is that domain practices need to be aligned to. Furthermore, even if a formalized strategy is present, it tends to be a moving target (Thompson, 1967); strategy changes as organizations adapt to circumstances making it a challenge to align domain practices continuously.

Secondly, organizational strategies tend to combine aspects of multiple distinct strategies (Collou, van Riemsdijk, Bruinsma, 2019). Accordingly, this raises the need for proportional design of the domain practices to align with organizations 'hybrid' strategies. For HRM, this entails that "an HR configuration should deviate from the ideal type HRM configuration exactly proportional to the extent to which the organizations' strategy deviates from the ideal-type strategy" (Delery & Doty., p.813). This need for fine-grained proportional design of domain practices presents a tremendous challenge.

Especially as thirdly, the domain practices tend to be numerous. Domain practices can be categorized in many subdomains in which multiple practices occur. One example is the HRM domain, in which many practices reside in the subdomains of recruitment & selection, job design, appraisal & compensation, training & recruitment (Collou, 2020). Another example is the IT domain in which a vast number of practices can be categorized into the subdomains service strategy, platform strategy, infrastructure design, security design, and operations & performance practices (Collou, Bruinsma, Iacob, 2020). Furthermore, these domain practices have not been specified to a level of detail needed by professionals that implement and apply them in organizations (Collou, 2020). In addition, these practices and their design are interrelated and need to show consistency amongst one another (Gratton & Truss, 2003).

Fourthly, even if the strategy is specified and a selection of aligned domain practices has been made, the outcome of that selection is characterized by nonlinearity (Miller and Friesen as cited in Meyer et al., 1993). Combining specific designs of IT service strategy and IT infrastructure practices, aligned to organizational strategy, could for example, increase performance greatly for a first period of time after which the effects decrease. Combinations could have different impacts and could not be a a simple sum of their parts.

Lastly, equifinality (von Bertalanffy, 1968) seems to occur; multiple combinations of domain practices can lead to similar outcomes. There is no 'one route to success. This makes it hard to pin down which specific combinations do and do not work (Collou, 2020). These complex characteristics of strategy alignment present significant challenges for professionals looking to increase organizational performance by designing a set of domain practices that align with the organizational strategy.

Games can be an effective tool to gain perspective on complex circumstances (Duke, 1974), like strategy alignment. Serious games enable the creation of an abstract representation of the reality of strategic alignment. Using that abstract representation, we can make professionals aware of the importance of alignment between strategy and domain practices; confront them with the vast amount of practices they can select from; challenge them to select and design domain practices; explicitize a theoretical concept, and provide professionals with feedback on the impact of their decisions. A serious game provides a way to present the challenge of strategic alignment to professionals without raising the need for an elaboration on all the aforementioned complex intricacies of domain practices to strategy alignment.Games furthermore provide the opportunity to gather empirical data, adjust the game models accordingly and feed theory development on the concepts represented in the game; in this case HR driven DT.

By combining game mechanics like collaboration and points collection (Hunicke, LeBlanc, Zubek, 2004), a serious game can leverage the 'fun' element of games to increase professionals' motivation to engage (Wouters et al., 2012) with the strategy alignment challenge. Hence, we set out to create a set of serious games that address the domain practices to strategy alignment challenge (Collou, Bruinsma, 2017; Collou, Bruinsma, Iacob 2020). These serious games have shown great potential. As designing domain (in this case HR) practices to steer employee behavior towards what is needed for the DT is one of the main challenges organizations currently face -and that challenge can be addressed effectively by designing HR practices to align to organizational strategy- we set out to create and present DITInLine, the latest addition to the set of strategy alignment serious games.

3. DITInLine, a serious game for the DT

HRM affects employee behavior through the alignment between the HR practices and the organizational strategy; the more aligned these HR practices are the more effective the shaping of specific employee behavior will be. However, as organizational strategies vary, the needed employee behaviors vary (Schuler & Jackson, 1987). This challenge of designing aligned HR practices for specific strategy-related employee behavior is captured and addressed in the serious game InLine (Collou, Bruinsma, 2017). However, the need for employee behavior related to the DT is relevant and urgent regardless of the specific strategy applied by an organization; both cooperative and adhocratic organizations, for example, need specific behaviors to cope with the challenges presented by the DT. This results in the multifaceted challenge of trying to select HR practices that align to the organizational strategy and increase the specific DT employee behavior. This particular challenge is addressed in DITInLine. As such DITInLine can be viewed as an add-on to or specification of the serious game InLine in which the challenge of designing HR practices for a particular strategy is addressed. Now, an elaboration of the theoretical underpinnings of DITInLine is presented after which the functionalities, flow, board and cards of the DITInLine serious game are elaborated upon.

4. Theoretical underpinning: strategy, alignment & employee behavior the DT

The theoretical underpinning of DITInLine is made up of the concept of aligning HR practices to organizational strategy on the one hand, and designing those same HR practices to increase the specific DT behaviors on the other hand.

The importance of HRM alignment has been a topic of importance in HRM research (Delery & Doty, 1996). Detailing the alignment between organizational strategy and HR practices in a serious game leads to a methodological need for a framework of reference. Based on that framework the organizational strategy and the extent of alignment between HR and that strategy can be specified. For DITInLine the competing values model (Cameron & Quinn, 2006) is used as a framework of reference. Accordingly, an organization can strategically focus on the effectiveness criteria 'flexibility' or 'stability', and on effectiveness criteria that emphasize an 'internal' or an 'external' orientation (Cameron & Quinn, 2006). Four strategic orientation types emerge: cooperative, adhocratic, mechanistic and market orientated, depending on the strategic choices an organization makes. These strategies initiate the need for different HR practices. An organization with a cooperative strategy, for example, is in need of HR practices that steer employees towards teamwork while an organization upholding an adhocratic strategy needs HR practices that facilitate innovative employee behavior (for a full description of these strategies and related employee behaviors see appendix 1). 72 HR activities were defined using the commonly applied HR categories recruitment & selection, appraisal & compensation, job design, and training & development. These HR practices can be selected and combined to align to these aforementioned strategies in the serious game InLine (Collou, 2020). DITInLine specifies InLine by introducing the challenge of designing for DT specific behaviors, in addition to designing for alignment. For a more detailed elaboration of the HR and strategy alignment challenge we refer to InLine (Collou & Bruinsma, 2017).

DT refers to organizational change shaped by the widespread diffusion of technology (Hanelt et al., 2021). As organizations set out to enhance their value proposition by embracing the DT they increasingly need employees to (1) adapt to the new technologies being employed and (2) perceive the opportunities presented by these technologies and enact changes proactively. Adaptivity is important; as new and evolving combinations of technologies are implemented employees need to adapt to, and safeguard or even improve their productivity using these new technologies. Hence, employees need to demonstrate flexibility towards new technologies, keep their job skills up to date, cope with uncertainty as these technologies change work procedures in a variety of ways, and adjust to these changes easily (Park & Park, 2019). In addition to these adaptive employee behaviors, organizations undergoing the DT need employees to show proactive behaviors (Doeze Jager et al.,

2021). This includes the anticipation of issues related to changes in the work environment, and the initiation and anticipation of solutions thereof (Chonko Jones, 2005). Employees with proactive agility look for new opportunities in the market and follow up, take risks, take advantage of possibilities, and implement new ways of exploiting (technological) opportunities.

Adaptive performance enables employees to adapt to technology driven change. Proactive agile behaviors add a layer of proactivity to these adaptive behaviors enabling employees to not only adapt well but also initiate change and exploit opportunities. The combination of adaptive performance and proactive agile behaviors constitute DT behaviors for the serious game DITInLine. To create DITInLine, these perspectives on HR alignment and the importance of HR activities that shape DT behaviors were specified and merged into the game.

5. Designing HR for alignment and shaping DT behavior

The main game goal of DITInLine is to increase the DT specific behaviors of employees using HR practices. The extent to which employees do indeed exhibit DT behavior is presented as the DIT score, a scale ranging from -20 to 100 during the game. -20 equals negative behaviors that hinder the DT while 100 represents ideal DT behavior. To increase DT behavior, players are challenged to select and combine an HR configuration out of a set of 24 HR practices (see appendix 2). These 24 HR practices were selected out of the aforementioned list of 72 HR practices tested, validated and implemented in the serious game InLine (Collou, Bruinsma, 2017). The selected 24 HR practices implemented in DITInLine were based on the extent to which these HR practices affect DT behavior, and also to safeguard potential alignment with the four different organizational strategies of the competing values framework. Subsequently, these individual HR practices were all provided with a score ranging from -50 to +50 that indicates the extent to which they increase or decrease DT behaviors of employees. These scores are based on HRM literature, and hidden for players during the game. During the game professionals select a combination of these HR activities trying to optimize the overall DIT score of the organization at hand.

However, the alignment of these HR practices and the organizational strategy is of importance. Therefore, this alignment was conceptualized in DITInLine as a variable that affects the increase or decrease of DT behaviors through the selected HR practices; the more aligned the selection of HR practices is to the strategy, the more leverage will be attributed to the increase in DT behavior. Hence, a set of HR practices can increase DT behaviors more effectively if that HR configuration is also aligned to the organizational strategy .This alignment 'leverage' variable is calculated using the strategic competing values focus scores included in each individual HR practice; job design focused on employees solving complex problems, for example, has 44 percent alignment score to the adhocratic strategy. These alignment scores were obtained using the solidified HR knowledge of HRM professionals (Collou, 2020). See figure 1 for a schematic representation of how alignment between strategy and the HR configuration affects the relationship between that same HR configuration and the DT behavior during the serious game DITInLine.

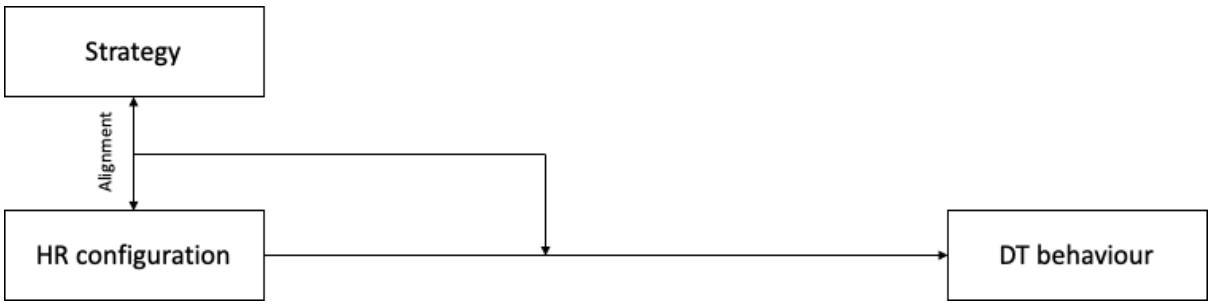


Figure 1: schematic representation of the relationship between strategy, alignment, the HR configuration and DT employee behaviors in DITInLine.

6. Flow and gameplay

DITInLine focuses on the key mechanisms relevant to professionals that set out to align the HR practices to the organizational strategy and affect DT behaviors, without being challenged by too much detail (Tsjernikova, 2009). Therefore, DITInLine focusses primarily on the combination of HR practices that can be selected and how those practices affects DT behaviors, affected by HR and strategy alignment. During a game session players go through the following steps.

Players are divided into teams of up to six professionals and play two to three rounds (e.g., years) of DITInLine sitting around the board of the game (see figure 2) that includes all the HR practice cards (see figure 3 for HR practice card examples).

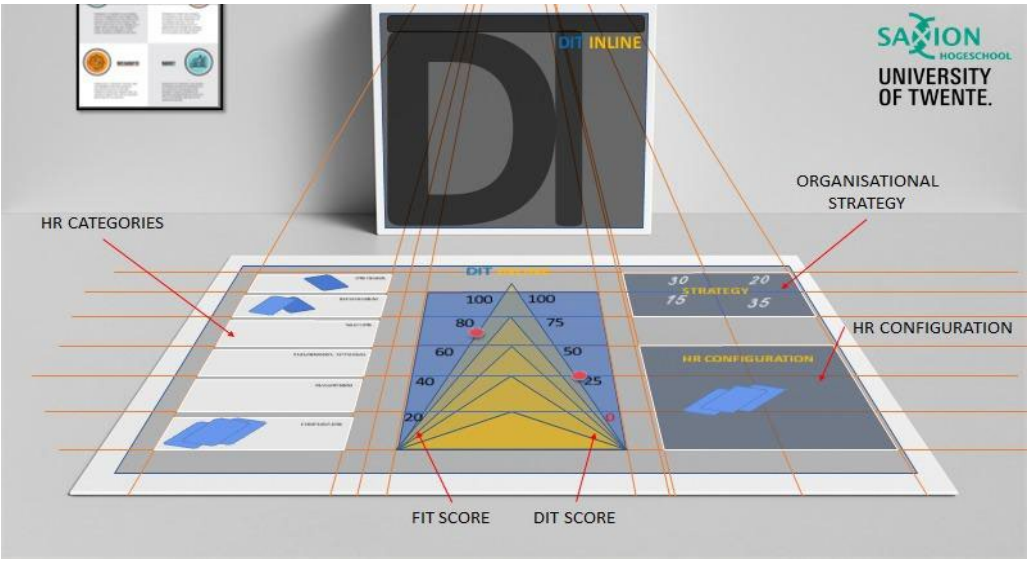


Figure 2: InLine board and cards.



Figure 3: HR practice cards examples

In step 0 players are introduced to the organization that they need to select and design HR practices for. This introduction includes a specification of the competing values strategy of the organization that the HR activities need to be aligned to, and an introduction of the CEO in which the need for DT behavior is made explicit and urgent. The strategy is displayed on the board as a reminder during the game. Once the players are familiar with the organization they start selecting HR practices out of the list of 28 HR practices as a team during step 1. After comparing the selection made between groups, supervised by the gamehost, players are challenged to prioritize their list of HR practices. Subsequently players are challenged to specify to a practical level of detail what they will start doing in terms of those specified HR practices. The final step in a round constitutes the evaluation of their HR practice selection based on the outcomes in terms of DT behaviors (bitscore) and alignment (fitscore). See figure 4.

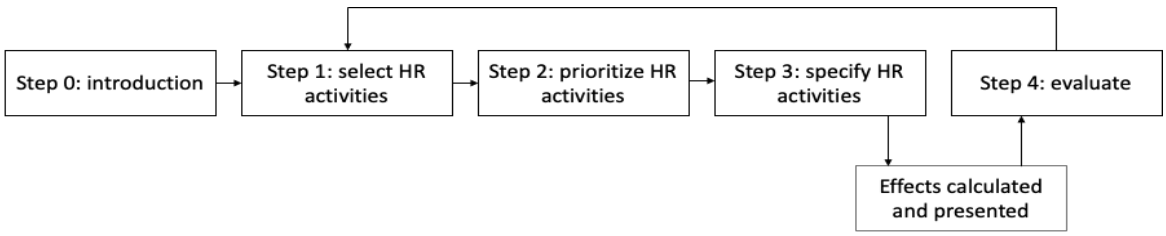


Figure 4: steps during a DITInLine game session

Game sessions are finalized by reflecting on the HR practices selected during the years, how these practices changed and a reflection of the systematic manner with which players focused on attaining an increase in DIT and FIT score.

7. Conclusions and future work.

Organizations are increasingly looking to embrace the benefits of the DT. As they do, challenges in terms of shaping the employee behavior needed to occur. The current paper described the design of the serious game DITInLine, a tool that can aid organizations and their professionals in their quest to optimize DT behaviors through the design of HR activities. During a DITInLine game sessions, players are challenged to select a combination of HR activities that increase DT behaviors and are aligned to the organizational DITInLine provides the opportunity to challenge professionals to make HR decisions explicitly in a playful but systematic way. Motivating professionals to use a systematic approach to increasing DT behaviors, taking into consideration strategy alignment, and providing insight in the outcomes of their decisions potentially increases the quality of their decision making. Furthermore, studying the decisions of professionals in their search for optimal DT behaviors can be a valuable endeavor that can be undertaken using this serious game as it enables studying and analyzing explicit HR choices. DITInLine represents the latest addition to a set of strategy alignment serious games that have shown great potential and outcomes.

As the design of BITInLine, in which the feedback on InLine is taken into consideration, is finalized, test sessions are being planned. The following categories of improvement are specified for the optimization of BITInLine. First, while the alignment scores of the HR activities used in BIFInLine are based on the solidified practical knowledge of HR professionals (), the extent to which they increase DT behaviors is solemnly based on literature. In future research, we strive to adjust these scores based on empirical assessments done by HR professionals. Secondly, defining and specifying potential additional HR activities that influence DT behaviors, and including their alignment scores, is a potential venue for future research. Thirdly, research needs to provide insight on the weighting of a combination of different HR activities. Currently, mutually exclusive practices, or combinations of synergistic practices, are not accounted for. Finally, while first impressions are positive, a more systematic approach to validating the learning effects of BITInLine is needed.

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Appendices

Appendix 1: Organizational strategies and related employee behavior

Cooperative employee behaviour	**Adhocratic employee behaviour**
Employees are focused on the quality of their work rather than speed. Employees enjoy working in teams, have listening skills, provide valuable feedback to colleagues, trust colleagues, divide the work equally and are willing to go the extra mile.	Employees are focused on improving current procedures/products and/or developing and implementing new ideas. Employees are independent thinkers, add value based on innovation, are experts and gain and share knowledge within and beyond organizational boundaries.
Mechanistic employee behaviour	**Market employee behaviour**
Employees are focused on well-defined procedures and rules that apply to their job. Employees read and comply with job manuals, are punctual, do not slack during working hours, conform to standard work hours and do not question status quo.	Employees are focused on competition. Winning is the ultimate goal and employees are willing to take risks. Profit maximization is achieved by catering to customer needs. Employees proactively search for new market opportunities and are eager to bring new products and procedure to the market.

Appendix 2: HR practices DITInLine

Nr	**HR practice**
1	The most important characteristic of job design is that employees need to solve complex problems.
2	The most important characteristic of job design is that employees need to cover other employees' work.
3	The most important characteristic of job design is that employees need to acquire their own assignments.
4	The most important characteristic of job design is that employees have to do clearly arranged work.
5	The recruitment of new employees is focused on accuracy of potential hires.
6	The recruitment of new employees is focused on the extent to which potential hires are able to attract new customers.
7	The recruitment of new employees is focused on the extent to which the potential hires can deliver craftsmanship.
8	The recruitment of new employees is focused on the extent to which the potential hires can come up with innovative solutions.

9	Employees' performance is assessed based on accuracy.
10	Employees' performance is assessed based on innovativeness.
11	Employees' performance is assessed based on commercial skills.
12	Employees' performance is assessed based on their collaboration with others.
13	New employees are hired due to their accuracy.
14	New employees are hired due to their ability to attract new customers.
15	New employees are hired due to their versatility.
16	New employees are hired due to their ability to come up with innovative solutions.
17	Employees are rewarded based on their innovativeness.
18	Employees are rewarded based on their commercial skills.
19	Employees are rewarded based on their production output.
20	Employees are rewarded based on their collaboration with others.
21	Employee development is focused on improving colleague collaboration.
22	Employee development is focused on increasing commercial skills.
23	Employee development is focused on increasing employees' ability to continue to perform assigned tasks.
24	Employee development is focused on increasing employees' ability to come up with innovative solutions.

Narrative Games in BioAnalytic Forensics

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Abstract: This paper reports on the use of branching path narrative games based on cases written by industry partners and built using Twine in a graduate BioAnalytic Forensics module. The ease of use offered by Twine made it suitable as a tool to quickly introduce industry partners to the concept of interactive narratives which assisted them in framing their case studies. Twine is also an effective tool for introducing these games to students who may be unfamiliar with the genre. Business constraints central to the problems and modelled in the games include time taken to resolve the problem, and the regulatory requirement to fully explore possible root causes of the issue. Assessment was based on student reflections on their experience in game play, and on their team case study writing.

Keywords: Twine, Biochemistry, Forensics, Game-based learning, Case Study method

1. Introduction

People make sense of the world by telling stories. We explain chains of cause and effect by embedding them in explicatory narratives - by telling stories about how things happened. This mode of understanding and transmitting knowledge dates back to oral tradition around the campfire. Iterations of even the simplest games - analogue or digital - can produce engaging stories of what events unfolded and how the end was reached. Creating interesting game spaces in which learners can explore a problem is therefore a powerful tool to help them capture learning in memorable stories.

2. Games & Simulations in science education

There are many reports and studies which describe the use of games and simulations in learning and argue for their benefits(Squire, 2011; Steinkuehler, 2012). Many studies offer examinations of the pedagogic value, the benefits to collaboration (Squire, 2007) alignment with learning outcomes or describe systematic approaches to evaluation of learning games (Mayer, 2012; Smale *et al.*, 2015). There are fewer studies of games in science education. Connolly (Connolly *et al.*, 2012) reviewed 129 papers from 2004-2001 but found only 11 related to games in science education. Out of 300 papers, Young (Young *et al.*, 2012) saw "little support for science-based serious gaming was revealed" A recent systematic literature review (Kara, 2021) out of an initial pool of 217 articles from the Web of Science identified 39 where full availability of the text allowed exploration of the studies. The bulk of the studies dealt with Experimental science, Biology or STEM education in general with only one specific to Chemistry. Most games were simulations of lab experimentation, and few aimed to improve 'scientific awareness skills', 'self-evolution', 'problem solving awareness' and 'interaction' which were key benefits of our approach. Of the age groups in the 39 papers reviewed by Kara, 10 dealt with primary age learners, 11 secondary and 6 undergraduate with 9 not indicated. This is a similar pattern to other systematic studies of game use in science education (Li and Tsai, 2013; Cheng *et al.*, 2015; Arici *et al.*, 2019) .

More recent literature includes some studies on serious games in science, but it remains limited. This shortage of reviews on games and gamification is pointed to by Kalogiannakis. Gamification, the subject of their systematic review is quite different to serious games but the literature does point to common ground in areas like improving “engagement joyfulness and motivation” and encouraging students to be proactive and reducing fear of failure (Kalogiannakis et al., 2021). A systematic review by Assaf et al also looked at adoption of game based learning in secondary schools, noting that early promises of easy adoption were unfilled and looking at issues with teachers, institutions and technology which affected adoption (Assaf et al., 2021). Liberona et al offer a recent broad survey of game based learning, gamification and serious games in the wider context of technology developments in higher education, with a particular case of entrepreneurship education (Liberona et al., 2021).

Interesting individual studies continue to focus on secondary level education. In reconciling game design methods with learning design in STEM games, a base narrative from a chemistry textbook was used to test a formal model of multiplayer serious game development based on activity theory, linking Goals, Feedback and Interpretation to extend the classic Mechanics-Dynamics-Aesthetics Game design methodology to create a

framework linking instructional goals, game mechanics and learning activities. The study dealt with secondary school chemistry, and engaged with teachers as designers rather than students as learners (Garneli et al., 2021) A Danish study to develop elementary students understanding of molecular studies in chemistry was designed in Unity 3D, but the actual student work was done in a 2D, not 3D workspace showing the value of using lower tech for serious games in STEM. Gameplay time was about 20 minutes which aligns to the play time in our work (Bjørner et al., 2021). In a Malaysian study involving 138 students, those using a serious game on chemistry learning outperformed a control group. Like many other cases, this study used secondary level students but unlike many others it did stress aims beyond disciplinary learning including collaborative skills and improving technological literacy (Lay & Osman, 2018).

There is a gap in studies on the use of games at graduate or professional education levels which we begin to address here. There is a lack of games which go beyond simulations to explore problems where the cause-and-effect narrative is more complex. We use Twine as tools to build games which address these gaps.

3. Twine

Twine is simple, graphical tool for creating interactive fiction. Originally designed to simplify the creation of hypertext interactive fiction stories, it has become popular for creating branching path games. The precursors of this genre include Fighting Fantasy gamebooks, and text-based adventures like the original MUD and the Infocom text adventures. Twine was developed by Chris Klimas and first released in 2009 (*Twine / An open-source tool for telling interactive, nonlinear stories*, no date). It became successful when it was taken up by the interactive fiction community. (Ellison, 2013) Current versions include support for JavaScript and, importantly, a visual editor which simplifies the editing process.

4. Biopharma industry in Cork

The Biopharmaceutical industry is an important employer in the Cork region, Ireland. This industry has a long history in the region, and now includes world class R&D as well as production facilities employing thousands of skilled graduates. A new postgraduate diploma programme at University College Cork has been developed in collaboration with several industry stakeholders in this field. This programme has been identified as of key importance for these companies in future proofing of graduates to meet priority skills needs in bioanalytical chemistry for these sectors. This initiative links strongly to Regional development and NDP/Project Ireland 2040 objectives, in particular strengthening relationships with enterprise. Partnering with industry in the design and implementation of the programmes as well as in the development of new innovative methods of teaching delivery such as virtual gaming has been a huge success. In particular, this paper will focus on the novel approach adapted to integrate industry scenarios into virtual games that are aimed at developing and enhancing problem solving and troubleshooting skills. This has been an excellent example of how industry and academia can work together to promote an industry-relevant teaching agenda and secure funding through the Human Capital Initiative (HCI) and deliver such a bespoke programme.

5. HCI initiative

A key aim of government policy has been providing graduates with the appropriate skills to support the continued growth of industries. As well as supporting STEM education at third level, there have also been initiatives like Springboard and the Human Capital Initiative which have specific, identified needs in the workforce. These initiatives fund the development of new programmes which are aimed at filling gaps identified by labour force surveys and industry consultations. The HCI funds new courses which are designed with industry input and participation.

The Postgraduate Diploma in Bioanalytical Chemistry is one such course. Industry partners involved in developing the course, and who deliver expert guest lectures and seminars include, MSD Brinny, Pfizers, Janssen, BioMarin, Regeneron, Eli Lilly, Thermofisher and Agilent. Several of these companies have collaborated in the design and development of virtual games based on industry scenarios that they have put forward as pilot case studies. These scenarios have been specially designed to complement the lecture material in the modules delivered as part of the Bioanalytical programme so that the student can leverage the knowledge base in the curriculum and apply it to playing and solving these scenarios in the format of a virtual game. A dedicated module was established to host these scenario-based games and provide a specific opportunity to assess problem solving in the overall context of the programme as the games span across multiple modules.

6. Industry case studies

The ownership of the case study method has been vigorously asserted by Harvard where it is traced to the School of Law in the 1870s and the Business School from 1911 onwards. In the Business school version, businessmen were invited to present a problem from their experience to the class and answer questions on it. The students then wrote a problem analysis paper which was critiqued by the business expert (Kimball, 2009). (DeLacey and Leonard, 2022) Whether they invented the method or not, this description is relevant here as this module drew on real world problems in the industry to design learning games for the students.

A key element of this module is that the problems which the students explore are predominantly based on real world problems encountered by the industry parties in their actual work. Cases were mainly written directly by industry partners, with some created by course team members based on knowledge of industry cases. The industry partners were invited to prepare case studies describing actual problems from their experience and outlining how those problems were solved. In most instances, the case studies were vetted by the firm's legal affairs teams to ensure no commercially sensitive information was revealed. This slowed the process but was necessary to allow for the release of the games to students and the possible release of some games as open educational resources.

The course team were already enthusiastic advocates of game-based learning. In order to bring industry partners onboard, it was necessary to host a seminar for them introducing game-based learning, interactive fiction games and Twine in particular.

The ease of use of the graphical editing environment in Twine was a key enabler in this process - while industry representatives grasped the general idea of game-based learning, it was the immediacy of an interactive demonstration of Twine which enabled them to translate their understanding into practice. The Twine demonstration was important for many industry partners in understanding how to 'chunk' problems into meaningful blocks in writing their case for students. This allowed them to view these cases in a new light and see the components of the problem and solution in a new way. It also meant that the cases studies as written were presented in a well organised way which made conversion into Twine games much faster.

The case studies presented by the industry partners included several elements about and beyond the core bioanalytical chemistry problems. In real world production, time and resources are often critical in determining the case of variances and resolving them. Thus, for example it might be necessary to track time taken to resolve an issue. For example, it might be essential to resolve a problem within 40 days. The investigative options at each step may take different amounts of time, and the games presented the learners with a choice between tests which might only take 1 day, or which might require 3 or 4 days. In some cases, the quick answer was the correct path to gaining more information towards a solution, but in others it was not, and time could be wasted by making a poor choice of investigation. (How this was tracked will be discussed below...)

7. Example of a Twine Game Screen

Example 1 - in the example the correct way to progress is option 2, although Option 3, since it saves time, is superficially attractive but incorrect

Question 2 : Breakdown the problem
You have discussed with your manager that in your opinion the priority is to identify the root-cause of the high oxidation values. Your manager mentions that the lab is under severe time constraints due to multiple projects ongoing simultaneously and asks you for more details on the problem to assess the criticality and urgency to solve this investigation.
What do you reply to your manager? Select the correct answer
Option 1: The origin of the samples is not critical, and you do not want to delay the start of the investigation since finding out these details will take 4 days. The important issue to resolve is the high oxidation values reported since it might re-occur in the next samples (4 Days)
Option 2: 2-You do not have enough information to answer the question fully. It is a priority for you to obtain this information, but you would need to go through the 4 W's process (who, what, when and where) first, although this process could take some time (4 Days).
Option 3: 3-You mention to your manager that you do not believe that the issue is related to the analysis. You have done preliminary research and have read that the levels of dissolved oxygen in the culture and culture temperature are known to be a major contributor towards oxidation. Since you have not encountered issues in the past with

similar types of testing, you anticipate that issue could have occurred during the cell culture process. You therefore do not expect that the investigation will involve many QC resources which are needed to support the other ongoing projects. (1 Day)
Days Taken: (2)/ 40

Equally, resources are not infinite. The learners progressing through the games could not expect lab tools or specialists to be at their beck and call in the real world, and they had to make choices based on the availability of those resources.

Other human factors were also presented in some of the cases. Work colleagues might not return results or information promptly because they were uncommunicative or unresponsive for various reasons. In some cases, these might have nothing to do with the workplace - health, or illness of a family member for example. Modelling them into the games meant players faced choices about how to deal with human issues and handle interpersonal problems in the workplace which affected the outcome of the investigation.

8. Root Cause analysis

The BioPharma industry is subject to strict regulatory controls, and one aspect of these is a requirement that any variances be comprehensively investigated. It is not sufficient to find an answer to a problem, it is also a requirement that the problem be fully investigated to exclude the possibility of any other contributory factor. The key methodology here is called "Root Cause Analysis". This is visually represented as a 'fishbone' diagram. To coin a phrase, it is necessary to fully bone the fish. Industry also applies the 5 why principle to determine the root cause of a problem. This is a very simple and effective approach to establish the origin of the issue being investigated and is used to prevent this issue from occurring again in the future.

9. Assessment

Assessment of the game play part of the module was based on student reflections on the game play. Students were not required to complete the games, but they were expected to progress though about 80% of 2 or 3 of the 6 games available to them. Ideally students would cover enough of the game content to satisfy the requirement to explore and eliminate possible alternative causes on the 'Fishbone' They were then asked to write a reflection of 500 words on their experience and what they had learned from the games.

In the second part of the module, students were formed into groups of 3 or 4 and asked to write a case study suitable for conversion to a Twine game. Students were shown Twine in the same way as the industry contributors had been, to assist them in creating structured case studies. Students were not expected to build their cases into a Twine game, but one group did produce a successful Twine game and one other attempted one. While most groups submitted their work as word documents, one also supplemented this with a limited decision tree.

Student cases were shorter and simpler than the industry cases. Groups which included students with more industry experience produced case studies which were broader and more challenging while groups which counted less work experience in their membership produced cases which were shorter and focused more on the science of the problem and less on other aspects of real-world production issues. Students reported that they found writing the case studies challenging. They particularly found it difficult to imagine a credible or interesting problem as a basis for the cases.

Grading overall for the module was a simple pass/fail and students who completed the required number of games, wrote a reflection, and contributed to the group case study writing passed. A key goal of the module was to expose students to real world problems, encourage critical and innovative thinking and develop skills in collaborative knowledge work in the domain.

10. Coding in Twine

Twine has two main story formats, Harlowe and Sugarcube. Harlowe is the easier of the two to use and most beginner friendly with significant built-in functionality and requires very little experience with code. Sugarcube has less functionality but can create a more varied and graphic heavy game. Snowman is also used as an advanced story format. Harlowe was the best in choice to make the games as reproducible and sustainable as possible.

In contemporary game development, accessibility with poor connectivity is something that is sorely lacking both in mainstream games as well as in game-based learning in academia. An aim for this game was to create something that was as accessible as possible for the work-from-home environment that was prevalent at the time of the creation of this project. The fact that Twine games are published to simple HTML files allows for them to be run on all levels of device and allows them to be self-contained and with a little work, completely independent from Wi-Fi. These games had very few graphics and graphics that were included were converted to base64 and embedded in the .html file to avoid the need for zip files to send out the students. The only aspect of these games that was dependent on internet connectivity was the data collection at the end. Using the history macro throughout the game and variable tracking the student could complete the game and collect their results without the need for an internet connection.

In one of the case studies, there was a time limit of forty days for a resolution to be found. To track time taken students stayed within the forty days, the variable '*$days*' was added, and each option had a certain amount of time attached to it. So, an answer may take one day or take eight days, students would choose the answer and depending on the amount of days assigned to it their day counter would change ('?/40'). If a student chose the wrong option, they would still lose that number of days to show real-world consequences for incorrect decisions. Some graphic effects and aesthetic elements may be added to make the student more aware of the passage of time such as colour changes in the days counter as students approach the deadline.

Thus at start the variable $daystaken was declared and set to 1

```
(set: $daystaken = 1)
1. You have 40 days (in game) to identify the root cause, most options will
have how many days it will take to execute the action assigned to it
```

The variable was incremented based on the students' choices as they moved through the game. Here it is incremented by 1 day:

```
(set: $daystaken += 1)
```

```
(text-colour:red)[''Incorrect, you have lost a days work'']
''Reason'' : :  without knowing the origin of the samples, you might exclude the right stakeholders from the investigation, who could provide details around the correct root-cause, and you cannot assess the criticality of the investigation
[[Go back -> Question 2]]
```

This example also shows an incorrect choice, styled in red, and offers the option to go back and try again.

Student pathways were captured with the history macros; you can also track macros as variables (*Is it possible to track the path of users through a branching scenario? - Twine Q&A*, no date) This was tested but required cross-domain permissions to a Google sheet. In future versions pathways will be tracked via the history macro. Students will then have the option to see the path they took through the game. This will also be of value for the lecturer to see the path they took and how it links to the reflection they write about their choices in game. At the end of the game, students can be presented with the pathway they took using the history macro. This pathway listing was not as clean as it could have been due to the naming conventions of the passages which were chosen to produce cleaner back-end code.

Ensuring the players adequately explored the root cause fishbone was controlled with a variable, $fishbone. Each key aspect, new revelation or piece of information was tracked by incrementing the variable $fishbone when they visited that passage in the game. There were also random points within the fishbone that were not required for the final answer which were counted with the variable $misc to ensure that students had adequately investigated the subject to the full extent as they would have to do in a real-world situation. The final passage in the game would only be revealed once the $misc and $fishbone variable had reached a certain number. This was necessary as in many real-world examples there would be multiple routes to the resolution of the investigation so the pathways had to be marked.

Here then we see the fishbone variable is initialised at game start:

```
(set: $fishbone = 0)
```

And incremented after the student has visited a branch of the fishbone
''Decision: YES to review the potential for Leaky bags''
''Outcome'': Luckily the bags are still in the area awaiting disposal, you perform a visual inspection and determine there was no leak – no assignable cause
[[Back to Materials -> 600]]
(set: $fishbone += 1)

Here we see the main switchboard passage of the fishbone, and at the bottom the code to allow the learner to progress to the final slide if they have visited enough elements of the root cause fishbone diagram (in this case, 14 steps on the fishbone).
''Decision: Fishbone''
- You have gathered together some experts on site to help you to brainstorm possible root causes for the OOS.
''(click on each header to decide which of the potential causes you should investigate next)''

- [[People -> 300]]
- [[Method -> 400]]
- [[Environment ->500]]
- [[Materials -> 600]]
- [[Measurement -> 700]]
- [[Machine -> 800]]

(if:$fishbone > 14)[=[[You have conducted sufficient analysis -> Final slide]]]

Creating a basic inventory in Twine just means creating a variable array. However, because the variables were so basic in these first games this was unnecessary. A development that will be added in later iterations of the games is the variables tracking the choice of specific team members to assist in investigating a problem or specific items in a lab investigation. This will involve more coding for these options, although it would be quite repetitive rather than complex. For example, an individual team member may have certain skills which would allow more options to be seen within the investigation or some team members may hinder the investigation due to personality or skills. Certain items chosen may allow for greater investigation within the game. This would require a full inventory of available lab equipment. Team members who had been chosen by the player to accompany them with the investigation would each need an in-game skills profile defined as an inventory.

For external data collection, the two main options were Microsoft Azure (Emilia, 2021) and data collection to a Google spreadsheet (Stewart, 2018). Microsoft Azure would have been the most useful as it allows for up to a thousand unique interactive online players when hosting a game. Numbers above that require a paid licence so it was not felt to be an option for accessibility and longevity of the project. If an academic institution wanted to use it, it is included within the Office365 licence. The other option was data collection to a Google sheet which requires around 60 lines of code inside of a coded Google sheet and 25 lines of code within the JavaScript in the Twine and on the last passage of the Twine to specify which variables are to be sent to the sheet at end of the game. However, an issue arose with that data collection method due cross-domain permissions with certain browsers.

The easiest route to develop for these games further would be to transfer them to Unity and to increase the interaction and graphics to create a more well-rounded gaming experience. Unity is a mainstream game development tool, but it is complex and not very intuitive. A way to make this type of game development process more accessible in Unity is with the use of the ‘Fungus’ plugin. Although no longer available from the Unity asset store the GitHub is active and regular updates and patches are released. Fungus is based on interactive narrative tools such as Twine and Yarnspinner and was created to help bridge that gap between the basic branching narrative process of Twine and the high-level game development aspects of Unity. There are also tools such as ‘Cradle’ available to convert Twine files directly into Unity game bases without the use of Fungus. However, this process can often become over complicated and difficult if you are new to Unity as a tool. Fungus as a tool has built-in functionality and pre-sets to start off building games and the original blog has numerous tutorials and videos on adding extra features such as active inventories, more complex character profiles and text to speech dialogue tools. Currently, we continue to develop these games in Twine as text and 2D graphics means more devices can support the games making them more accessible to students. The plan is to eventually move into

parallel development in full 3D realm using Unity to create a high-level immersive gaming experience that will create an active learning environment.

11. Conclusion

This use of industry case studies in branching path games exposed learners to real world problems which include real industry issues beyond the lab including personnel issues, resource use, scheduling and regulatory requirements which are not covered in most simple simulations in the field. Learners were required to explore alternative pathways to solutions, creating learning stories in which wrong turns and backtracking to find the correct solution were important parts of the learning. Having been exposed to this way of presenting problems, learners were then better able to creatively imagine possible problems in the field. They were also better able to break down those problems into discrete issues and 'chunk' them into manageable tasks which could be presented to future cohorts in the Twine game format. The reflection-based pass/fail assessment model encouraged exploration of a variety of approaches to both the game play and collaborative case study creation. This allowed learners space to develop a deeper engagement with the problems.

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Players' Reflections on Digital Games as a Medium for Education: Results from a Qualitative Study

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Abstract: The use of digital game potential for education has been investigated extensively. However, little is known about how players themselves perceive educational possibilities of the entertainment games they play in their free time. This knowledge gap is problematic because players' own assumptions about learning with digital games will influence the acceptance and the outcome of any game-related educational intervention. Based on a qualitative content analysis of interviews with 19 adolescent and young adult players of five simulation games (Age of Empires, Cities Skylines, Civilization 6, Eco, and Tropico 6), this study investigates how players perceive digital entertainment games as a medium for (geography) education. While a few interviewees dismiss the potential of digital (entertainment) games, predominantly based on the games' contents instead of medial particularities, others embrace the educational possibilities of the medium wholeheartedly, based on its attractiveness and unique characteristics, including didactical features. A third group of respondents provided mixed reviews of (entertainment) games' educational potential by referring to advantages and disadvantages of the medium's characteristics, as well as the challenges of a simplified and/or inaccurate representation of content. Interviewees from all three groups underestimated the value of digital games for (geography) education beyond subject matter expertise. By solely framing (geography) education as the transfer of correct and politically neutral specialized knowledge, they failed to recognize games' possibilities in terms of achieving additional learning goals of contemporary (geography) education, such as critical reflection skills, argumentation skills, and the formation of opinion. Overall, many players rightly assume that a successful implementation into the geography classroom strongly depends on context variables, such as the selected game, target group, learning goals, and pedagogical concept. Above all, they stress the importance of briefing and debriefing by an educator. Finally, the players' levels of reflection and depth of argumentation varied significantly – presumably depending on their age, educational level, and the games they refer to.

Keywords: game-based learning, geography education, qualitative methods, media literacy, players, simulation games

1. Introduction and theoretical perspective

Researchers and practitioners who are contributing to the field of digital game-based learning carry comprehensive assumptions about players' learning with digital games derived from personal and professional experiences as well as academic studies (e.g. Steinkuehler, Squire and Barab, 2012). It is taken for granted that both educational and entertainment games do not just lead to informal learning processes, but should be applied in formal education, though details, such as effect sizes and pedagogical preconditions, are highly debated. There is also a detailed understanding of what teachers believe with regard to the possibilities and limitations of digital games in classrooms (e.g. Bourgonjon *et al.*, 2013; Beavis *et al.*, 2014). Not surprisingly, teachers' general attitudes to a classroom implementation of digital games are more diverse and, depending on who is asked, are more critical when compared to the professional community of game-based learning researcher and practitioners.

In contrast, we know little about how players themselves perceive the educational potential of digital games. Whilst there are some mostly survey studies about students' general acceptance of digital games for classroom learning (e.g. Bourgonjon *et al.*, 2010) and their experiences and perceptions of digital games in the classroom after they have been exposed to them (e.g. Beavis, Muspratt and Thompson, 2015), players' imagination about how the entertainment games they play in their free time could be used in formal (geography) education have not been explored in depth yet. This gap in knowledge is problematic because the implementation of entertainment games is increasingly favored over educational games (e.g. Martinez, Gimenes and Lambert, 2022), and players' own assumptions about learning with digital games will influence the acceptance as well as the outcome of any game-related educational intervention (e.g. Giannakos, 2013). Therefore, the present paper focuses on adolescent and young adult players' assessment of entertainment games that they play in their free time. Age of Empires, Cities Skylines, Civilization 6, Eco, and Tropico 6 have been selected due to their relevance in geography education as they cover topics such as climate change, city development, migration, and resource management, and their commercial and/or critical success. All of them fit into a particular genre of simulation games. Previous studies have shown that for geography education these games are particularly promising with

regard to the promotion of specialist knowledge about topics such as climate change and resource use (Lux and Budke, 2020a), the demonstration of systemic interrelationships (Lux and Budke, 2020b), and the facilitation of dynamic decision-making (Czauderna and Budke, 2020, 2021).

Consequently, the present paper intends to answer the following research question: How do players reflect on the simulation games they play in their free time (for entertainment purposes) as a medium for geography education? To answer this research question, we conducted a qualitative content analysis (Mayring, 2004) of 19 interviews with adolescent and young adult players of the five simulation games.

In the context of this paper, we understand the concept of reflection (see e.g. Brockbank and McGill, 2007) as critical evaluation of and argumentation about digital games in terms of their potential for (geography) education, as part of a wider games literacy (Buckingham and Burn, 2007). We furthermore assume that an adequate reflection on digital games as a medium for education requires a consideration of three distinct objects of reflection: (1) the games' learning contents; (2) the games' structure/mechanics (compared to other media) and; (3) the games' (potential) classroom implementation/the educational context. In our analysis, we examine all of these areas separately in three different sections (3.1.-3.3), before we investigate individual differences in level of reflection and media literacy from an overall perspective in the final section (3.4).

2. Methods

This study relies on a qualitative content analysis (Mayring, 2004) of 19 semi-structured interviews with 16 adolescent and young adult players of five simulation games (Age of Empires, Cities Skylines, Civilization 6, Eco, and Tropico 6). Interviewees were between 12 and 22 years old, with 3 interviewees identifying as female and 13 identifying as male. All interviewees are avid players of at least one of the games. Each interview focused on one of the games. In the case of three players we conducted two interviews or split the interview in two parts, covering one of the games each. The following table shows a summary of our interviews – including our interviewees' age, gender, and the game(s) discussed:

Table 1: Overview of interviews/interviewees

ID	Age	Gender	Game
I1a I1b	22	male	Age of Empires (AoE) Cities Skylines (CS)
I2	12	female	Age of Empires
I3	19	male	Age of Empires
I4	15	female	Cities Skylines
I5a I5b	18	male	Cities Skylines Civilization 6 (Civ)
I6	13	male	Cities Skylines
I7	18	female	Cities Skylines
I8a I8b	18	male	Cities Skylines Civilization 6
I9	22	male	Civilization 6
I10	18	male	Civilization 6
I11	19	male	Civilization 6
I12	20	male	Eco
I13	13	male	Eco
I14	20	male	Eco
I15	20	male	Tropico 6
I16	20	male	Tropico 6

All interviews were conducted in the German language and, as such, the quotes in this paper are translations by the authors. While the interviews were broader in scope, focusing on, for example, players' assessment of their own learnings and the games' representation of reality when it comes to topics relevant for geography education such as climate change, city development, migration, and resource management, the analysis mainly investigates interviewees' answer to one of our main questions "How would you feel about using game X in geography classes?" and follow-up questions which aimed to get players to justify their opinion. After formulation of our research question, interview transcripts were inductively coded according to qualitative content analysis (Mayring, 2004), using the software MAXQDA. The final code system consists of the following categories:

1. Positive evaluation of the potential of games for (geography) education > based on their medial characteristics/structure
2. Positive evaluation of the potential of games for (geography) education > based on their content
3. Negative evaluation of the potential of games for (geography) education > based on their medial characteristics/structure
4. Negative evaluation of the potential of games for (geography) education > based on their content
5. Reference to/discussion of classroom implementation (including the role of educators)
6. Passages that (contain) signs of media reflection/games literacy
7. Passages indicating that reflection is absent

In the following results section, we use text coded into categories (1), (2), (3), and (4) to outline how interviewees assess digital games as a medium for (geography) education based on their contents (3.1) and on their structure/game mechanics (3.2). Afterwards, we describe their assumptions about the implementation of digital games in the classroom, coded into category (5) (3.3). Throughout these sections, interviewees' level of reflection and media literacy becomes implicitly apparent, which is discussed at the end of each section. Finally, we investigate individual differences in level of reflection and media literacy, as coded into categories (6) and (7) (3.4).

3. Results

3.1 Assessment of digital games as a medium for geography education based on their contents

When asked to what extent digital games are suitable for incorporation into geography lessons, some of the respondents answered that they see similarities between the topics of the games and the topics of geography lessons and therefore think it makes sense to use them. The topics of urban development and urban planning are mentioned particularly frequently (particularly those including location factors, functions of the city, and functional division of cities) as well as climate change and (sustainable) use of resources. An example is given in the following interview quotation:

> *"Oh, climate change and how valuable resources are, how rare resources are, but also to some extent action and how our global society works."* (I12, 20 years old, male, Eco)

Single interviewees also mentioned topography, plate tectonics, social inequality, and, as in the quote, globalization as appropriate topics. In this context, it was noted in a number of cases that many digital construction games are a simulation of the world, which the players can explore in their systemic connections through an explorative approach:

> *"Then you could let students try out for themselves how they can get a city to grow and how you can ensure the economic survival of the city, the functional structure of the city with industry, commerce, housing, leisure and so on, trade with other cities can also be represented by building export-oriented industry and so on, that can be simulated very well. You could then simply commission different scenarios for the students."* (I5, 18, male, CS)

However, the quality of the game-based simulation in terms of reality outside the game is judged to be too low for incorporation by the other part of the interviewees, and from this it is deduced that they are not suitable for geography lessons:

> *"[The classroom use of digital games] would probably rub some students the wrong way because like I said before, it's not really realistic."* (I2, 12, female, AoR)

This interviewee also thought that digital games present mainly fictional content and therefore considers them unsuitable for learning about real issues in geography lessons. This view is supported by interviewees who suspect that other game elements, such as victory conditions, combat actions or the narratives in the games are more dominant than the content, and therefore distract from learning:

> *"I don't think that would fit or I would find that bad, because it is very much based on this combat aspect. And if at all, because in my game that's not the case at all, but if at all then this climate aspect generally comes very late into the game and these effects, they then also, as I said, become noticeable, but not noticeable enough for that to somehow make an impression."* (I8, 18, male, Civ)

One respondent also expressed fear that digital games, which, in some cases, include politically controversial content, could manipulate and politically influence students:

> *"I wouldn't take Tropico like that. It is sometimes not politically correct. I, for example, like to play things that I wouldn't support in the real political world. But people who are very impressionable or very young, I do think that the actual events are often underestimated because you have a relatively trivialized version of the game*." (I16, 20, male, Tropico)

In summary, there were very few subject-related topics mentioned in the interviews that were thought to be dealt as well in digital games as in geography lessons and consequently would be appropriate for incorporation into lessons. The assessment of the suitability of the games for teaching varies greatly between respondents, thought to be due to different understandings of how each of the games simulated topics that are also covered in geography lessons. Some of the interviewees considered the learning of content through the games to be possible, particularly the possibility of understanding systemic relationships through playing. Another group of the respondents considered the games to be too fictitious, too simplistic and therefore unsuitable for teaching subject knowledge.

The interviewees' focus on teaching expertise through digital games only relating to a limited number of topics is probably due to a limited understanding of geography. Therefore, the importance of teaching competencies in the area of spatial orientation, communication, personality development and assessment, which are important components of geography lessons, are not likely to be associated with digital games. Some of the respondents saw many deficits in the games with regards to conveying subject knowledge. However, the statements in this area were often very vague, which is thought to be due to their lack of subject matter expertise. In addition, the predominant understanding seems to be that all teaching media have to present comprehensive, correct and politically neutral knowledge. However, such an approach means that students would then not be given any starting points for training their critical reflection skills, argumentation skills and also little impetus to form opinions, all of which are central skills goals in contemporary teaching. Finally, the role of the teacher, who embeds the media into the lesson and can initiate reflection, is not considered in some cases.

3.2 Assessment of digital games as a medium for (geography) education based on their structure/game mechanics

When our respondents agreed there was potential in the use of games as a medium for (geography) education, their argument was predominantly based on the games' structure, and particularly their mechanics. They, for instance, refer to motivational aspects, as the following quote documents:

> *"I think you can use the game at the beginning of the topic of urban planning. So, as a kind of introduction to the topic.* ***The game can arouse much more attention and interest.****"* (I7, 18, female, CS)

The interviewees furthermore refer to the games' interactivity, as in this quote: *"Yes, I mean, you can bring that up in a very* ***interactive way****."* (I12, 20, male, Eco)

Thereby, the focus is mostly on the possibility to act as a player, while the feedback of the games is barely mentioned. The following quotes emphasize players' active role as a unique feature of the games with educational potential:

> *"I think that would be good, because it would definitely be a change from the current geography lessons and then you could let students* ***try out for themselves*** *how they can get a city to grow and how you can ensure the economic survival of the city, the functional structure of the city with industry, commerce, housing, leisure and so on."* (I5, 18, male, CS)

> *"And I think if you* ***experience it actively*** *in such a medium and also* ***play it yourself*** *and not in a framework where it becomes directly so pedagogical, but where you also open up the whole thing yourself and you also work with these consequences or these principles in the game, so you really have to apply it practically in the game this topic, how do I make the industry there now? How do I dismantle it and how do I make the best possible use of my environment? That's why I think this medium is very suitable."* (I14, 20, male, Eco)

In many cases, respondents frame the games' interactivity and their inherent learning potential in contrast to other educational and/or entertainment media:

> *"I would definitely find it very cool, because then **you can just try things out** and so vividly and I think **that's better than just working with a book or something**."* (I4, 15, female, CS)

> *"I think computer games have even more influence than other entertainment media that used to have those influences because you interact with it more and it doesn't just affect you like when you watch a movie then maybe I can think about it but you can't change the story like when you have a game now. Then of course you can take a lot of influences on how you play your game or you can learn a lot better with it because if you do something you learn more than if you just read through or watch something."* (I16, 20, male, Tropico)

It is apparent from quotes thus far that many players argue for a classroom implementation of games based on features such as interactivity and action-orientation, which build up play, to facilitate/support learning. However, other players were less optimistic and referred to game features when questioning the value of games for educational purposes. They, for instance, thought that games are difficult to assess for some players due to their level of difficulty and required time:

> *"I think the problem then is more with other aspects. I think you can use the content pretty well for that, actually. I think the problem is simply that most people wouldn't be interested in getting to grips with a game like this, because it's – You can play the game for 30 minutes, but then you haven't got through the tutorial yet. But I think that's more the problem that it's just not – I don't know what it's called in German, but **it's just not accessible enough**, I think."* (I15, 20, male, Tropico)

Additionally, some interviewees perceived play and learning as contradictory:

> *"You would just have to think about how to make sure that people would then engage with it. **Not just playing the game, but really learning.** Somehow. I find that difficult."* (I9, 22, male, Civ)

Despite the concerns of some respondents, most considered games to have potential to be meaningfully applied in (geography) education. Respondents in favor of games' classroom implementation referred more to structural features of the games (game mechanics) than to their contents. As experienced players they bring a certain degree of games literacy as they know characteristics of games, such as interactivity, allowing them to competently relate to these characteristics in their argumentation. However, their understanding of interactivity is incomplete. When discussing interactivity, they mostly focused on the player, the possibility to act, whilst neglecting the side of the game and consequently failing to explain the important role of game feedback. It is thought these respondents derived their analysis of games' classroom implementation from their own motivation of playing games in their free time and therefore overemphasize their own actions. Overall, the majority of interviewees responses were not specific to geography education and instead referred to general classroom education and/or are transferable to other subject areas.

3.3 Assumptions about the classroom implementation of digital games

When asked how digital games could be meaningfully integrated into geography lessons, the majority of respondents referred to the teachers, from whom they expect to incorporate game play through didactic planning. The respondents thought teachers should select games that contain complex content and fit the learning groups in terms of gaming experience and content knowledge. In many cases it was said that the unreflective use of games alone would not be sufficient to achieve a learning effect:

> *"So, I don't think it would have any benefit if you just let the students jump into the game."* (I10, 18, male, Civ)

Reference to lesson planning included choice of the didactic setting in which to use the game. In this context, several respondents considered the introduction to the lesson to be particularly suitable, and justify this by saying it would motivate students about the main lesson topics, which could be triggered in the students through the use of the game:

> *"I think you can use the game at the beginning of the topic of urban planning. So, as a kind of introduction to the topic. **The game can arouse much more attention and interest**."* (I7, 18, female, CS)

The possibility of activating prior knowledge through the use of games in the introduction was also mentioned. Furthermore, some interviewees consider the limitation of the genre-specific long play time to be relevant and the concentration on game scenes or levels to be of great importance for the topics dealt with in class. In this context, the following player suggested, for example, that in the game Civilization only a particular age may be selected to be played in class:

> *"I would maybe take the individual ages, because you can also do that when you create a game, you can also limit everything to a number of years and just start there in that age or in that age and then **limit the whole thing so that you only concentrate on a smaller area** and don't just gamble through, but really take the whole thing – take your time for it and only take the things from the industrial era, for example, and then go further later."* (I9, 22, male, Civ)

Players also made suggestions about the appropriate social form for playing in the classroom. In this context, playing in groups is seen as particularly suitable. In addition, players suggest that teachers produce assignments to guide playing of the games. According to the interviewees, reflecting on the game after playing would be of paramount importance. In particular, the importance of reflection on the correctness of the content presented in the game in comparison to reality was emphasized, an example of which is seen in the following quotation:

> *"I think in terms of content, it can definitely be used, if of course it is also **commented on with the teachers** that this is not so true after all – **the aspects that are then not so realistic**."* (I15, 20, male, Tropico)

Furthermore, it was suggested that reflection on the internal reality of a game could be undertaken whilst playing and pausing the game:

> *"And then a reflection, in a way: What is happening right now? Why is this happening? Are there other solutions? How can this be prevented? In other words, we should go into detail about what is actually happening."* (I10, 18, male, Civ)

In summary, the players expressed a wide range of ideas on how games can be used positively in geography lessons. In addition to the didactic selection of the game to be used, the embedding of the game in the lesson was a central concern, which was considered to be connected with tasks during the game and for the preparation and follow-up of the game. However, the ideas expressed are for the most part quite vague, which is not surprising since the interviewees have no didactic training.

3.4 Individual differences in level of reflection and media literacy

As identified in previous sections, a lot of players are able to critically reflect on digital games as a medium for (geography) education, referring to their contents (3.1), structure/game mechanics (3.2), and possible educational context (3.3.). However, we have also outlined its limits. Overall, we assume that the level of reflection and depth of argumentation, as part of games literacy (Buckingham & Burn, 2007), vary significantly between people: from having no imagination of how entertainment games may contribute to formal education or a naïve appreciation of their attractiveness (without backing up the respective position with solid arguments) to a sound understanding of how digital games function as educational medium (in contrast to other media and didactical approaches) and comprehensive ideas and suggestions as to how they may be implemented into a (geography) classroom, and visionary and/or balanced evaluation of classroom implementation (see 3.3). Obviously, this may partly depend on the respondents' age, educational level, and the games they refer to, which should be investigated in future research.

The following quote reveal one of the players' high level of educational games literacy, as he has a sound understanding of how digital games can function as educational medium with regard to various social issues, such as climate change and resource use, in comparison to other media and didactical approaches:

> *"So such games, of course, are clearly time-consuming, I think such contexts could also be crammed into a 1 ½ hour seminar, but that's not active for the people who are supposed to learn something from it and I think if you experience it actively in such a medium and also play it yourself and not in a framework where it becomes directly so pedagogical, but where you also open up the whole thing yourself and you also work with these consequences or these principles in the game, so you really have to apply it practically in the game this topic, how do I make the industry there now? How do I dismantle it and how do I make the best possible use of my environment? That's why I think this medium is very suitable."* (I14, male, 20, Eco)

In contrast, other players showed no imagination of how entertainment games could be implemented into the (geography) classroom, as the following quotes from two younger players show:

> *"Now this is kind of strange to me because teachers generally don't use games, but if they did use them, [that] would probably rub some students the wrong way because like I said before, it's not really realistic and yeah, you can't say that quickly now." (I2, 12, female, AoE, when asked how she would find it when teachers used AoE in geography classes to teach city development and resource usage)*

> *"I think that's okay. It just doesn't have to be. But you can do it." (I13, male, 13, Eco)*

Others younger interviewees appreciated the value of digital games for classroom application, probably intuitively, but were not able to back up their position using solid reasons. I6, for instance, said that he:

> *"would actually find that [the application of digital games in education] quite exciting because it's just fun like that and of course you learn something in the process and yes."* (I6, male, 13, CS)

The interviewee neither delivers an explanation why it may be important to have *"fun"* in school with games nor what to *"learn something in the process"* means. When asked about what he has learnt previously in informal play, such as city development in Cities Skylines, his lack of reflection was equally apparent:

> *"That it's just not that easy, yes, and that everything has to be right, so to speak, or something. I do not know."* (I6, male, 13, CS)

Overall, this younger player does not seem to be able to verbalize both his learnings during informal play and, on a more abstract level, why and how digital games could be a promising medium for education.

4. Conclusions

Based on a qualitative content analysis of semi-structure interviews with 19 adolescent and young adult players of five simulation games (Age of Empires, Cities Skylines, Civilization 6, Eco, and Tropico 6), this study focused on how players feel about the use of digital entertainment games as a medium for teaching in (geography) education. While a small number of interviewees dismissed the potential of digital (entertainment) games, mostly based on the games' contents instead of medial particularities, others embraced the educational possibilities of the medium wholeheartedly, based on its attractiveness and unique characteristics (known to them from their own experiences). A third group of interviewees delivered mixed reviews of (entertainment) games' educational potential by referring to advantages and disadvantages of the medium's characteristics, and to challenges of a simplified and/or inaccurate representation of content.

The observed variation in attitudes towards and evaluations of learning with digital games correspondents to results from previous mostly quantitative research investigating students' experiences and perceptions of digital games in the classroom including a study by Beavis, Muspratt and Thompson (2015) that found, among other things, noticeable differences between girls and boys.

In general, in our study, most interviewees underestimated the value of digital games for (geography) education beyond subject matter expertise. By solely framing (geography) education as the transfer of correct and politically neutral specialized knowledge, they failed to recognize games' possibilities in terms of other learning goals of contemporary (geography) education, such as the promotion of critical reflection skills and argumentation skills as well as the formation of opinion. However, many respondents understood, that a successful implementation into the geography classroom strongly depends on context variables, such as the selected game, target group, learning goals, and pedagogical concept. Above all, they stressed the necessity of briefing and debriefing by an educator, which fits with the current state of research (see e.g. Crookall, 2014).

Overall, players' level of reflection and depth of argumentation varied significantly, thought to be controlled by their age, educational level, and the games they referred to. The respondents varied from having no imagination of how entertainment games may contribute to formal education or a naïve appreciation of their potential but not providing evidence for their position, to comprehensive ideas and suggestions of how digital games may be implemented into the (geography) classroom.

The practical implications of our results are twofold:

1. By taking players seriously as experts in both digital games and their own learning habits/preferences, as well as reflective students who know geography education from their own experience, our results offer conclusions for the design of educational games and educational practice alike. In this context, it is of particular importance to consider that the players' own assumptions about learning with digital games will influence the acceptance and outcome of the classroom use of digital games (e.g. Giannakos, 2013). Furthermore, it must be taken into account that players differ in their attitudes towards learning with digital games. Thus, as Beavis, Muspratt and Thompson (2015, p. 39) conclude, in curriculum design and educational practice, "it is important to attend to the voices of all students and to meet students 'where they are at'. In technological times, as always, diversity matters."
2. By shedding light on our interviewees' unequal ability to reflect on games as educational technology, our results point to the need of media education to increase games literacy of players (Buckingham and Burn, 2007) in particular and media literacy (Livingstone, 2004) in general. The sub-literacy we investigated may be part of what may be called "educational games literacy".

In conclusion, the results of our qualitative study on players' reflections on digital games as a medium for education must be seen as exploratory. Among its limitations is that the concept of media literacy has not been operationalized and systematically measured. Furthermore, the age range of our limited amount of participants is large. The level of cognitive development of a 12-year-old is not comparable with a 22-year-old, which will have impacted the results of this study. In addition, it must be mentioned that we did not include players with little or no experience with relevant games. Finally, we approached the topic from the perspective of one school subject (geography) and only included reflections on one particular genre. Future studies must operationalize and systematically measure the concept of media literacy, consider variables such as age, gender, educational background, gaming experience, and include reflections on other genres referring to a variety of other school subjects.

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Hack the Map 3D Video Game: Escaping your destiny through Rigas' Charta

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Abstract: Celebrating the two hundred years from the Greek Revolution of 1821 and the War of Independence, Onassis Library, in collaboration with the Cartographic Heritage Archives of General State Archives of Greece and the Department of Geography of Harokopio University, implemented a series of digital workshops on 3D video game design in order to motivate teenagers to interact with one of the most emblematic maps of the eighteenth century and a major artefact of the Greek cartographic heritage: Rigas Velestinlis' Charta (map) of Greece (1796–1797). In 2020, four (4) school teams consisting of sixty-five (65) students 13-17 years old, brought to life the map that inspired the Greek Revolution of 1821, transforming it into a 3D video game for PC or Android devices. By using innovative mixtures of history, geography, cartography, visual arts, and information technology, they managed to build a third-person puzzle game with one hero (Rigas) who had to run through the Charta region to escape imprisonment by solving twelve (12) riddles, collecting all the scattered sheets of the revolutionary map and unifying its parts. This educational activity broke out of the traditional classroom routine, enhanced the engagement, collaboration, and communication of the youngsters, fostering their creativity and their connection with the cartographic cultural heritage. Learning through game-making stimulated literacy development and improved the digital skills of the participants. The success of this innovative educational experience led to the development of an Augmented Reality (AR) application entitled "Rigas' Charta," available at Google Play for Android devices and to the implementation of the game-developing course to an online National Student Competition entitled "Hack the Map: Rigas' Charta" for the school year of 2020–2021.

Keywords: 3D Video Game, Historical Cartography, Rigas' Charta, Digital CartoHeritage, Escape Rooms, Game Based Learning (GBL)

1. Introduction

The Onassis Library is a cultural space which holds a great number of historical objects, documents, archives, and artworks, that became accessible to the public in 2016. Since then, the library has been organizing educational and cultural programs inspired by its special collections, promoting its cultural wealth by investing in research, education, and new technology techniques. In 2020, commemorating the 200th anniversary of the outbreak of Greece's War of Independence from the Ottoman Empire (1821), the Onassis Library in collaboration with renowned institutions implemented the digital workshops entitled "Hack the Map: Rigas' Charta." This innovative program motivated sixty-five (65) students 13-17 years old to reuse and reinterpret the Charta, through new technology tools and digital applications.

Rigas' Charta is a 12-sheet map (each ~50×70 cm), printed in Vienna in 1796–1797, which is widely considered the most prominent example of Greek cartography in the pre-revolutionary period (18th c.) (Figure 1). The creator of the map, Rigas Velestinlis (1758-1798), a scholar, secretary in Ottoman administrative hierarchy, wealthy merchant, and prominent personality of Modern Greek Enlightenment, is known for his radical activism. His progressive views about the role of education in creating citizens devoted to the idea of personal, national, and social freedom and his liberal ideas in the spirit of French Revolution about the creation of a free, democratic pan-Balcanic Respublica, influenced the Greek War of Independence (1821-1830), as well as similar movements between the neighboring people in the Balkans (Daskalakis, 1937).



Figure 1: Rigas' Charta of Greece, 2x2 meters, 12 map-sheets, Vienna, 1796–1797, source: Onassis Library, photo: Yiannis Soulis

By combining the scientific fields of history, geography, literature, computer graphics, and visual arts, "Hack the Map" digital program aimed at rediscovering a primary source of great cultural value, a so-called 'multimedia' of the eighteenth century, inviting school teams to study it, to decipher the meanings of its iconographic elements, and to bring to life the mythical stories and historical events that are engraved on it. This interdisciplinary educational initiative developed an innovative educational model for teaching, by applying OBL (Object-Based Learning), GBL (Game-Based Learning), and PBL (Project-Based Learning) approaches. Through four (4) training sessions (12 hours), the participants managed to upgrade their digital skills and enhance their scientific knowledge. They became technology creators, they came across historical documents, old editions, and archives, familiarized themselves with Hellenic cultural and cartographic heritage, and explored interactive ways of reusing rare material, modifying and promoting it, in order to attract and engage a younger audience. The result was the creation of a 3D video game based on Rigas Velestinlis' life and works, entitled: "Escaping your destiny through Rigas' Charta". The title of the Game was inspired by the importance of this historical document regarding Rigas Velestinlis' fate, as he was arrested trying to transfer the copies of this map from Vienna to Trieste and this cartographic element was characterized as the main incriminating evidence, that led to his martyrdom (Legrand, 1892, Livieratos, 2008). An interesting detail in his biography, is that when he was arrested, he had also in his luggage a German history card game (Legrand, 1892). Being open to new pedagogical methods and an advocate of lifelong learning, Rigas, definitely could be considered as a pioneer in GBL and OBL.

2. Game Description

After an introduction to the history of cartography, focusing on the age of Enlightenment in eighteenth-century Europe, and analyzing the personality and works of Rigas Velestinlis, the students studied educational material provided by the Onassis Library and the Cartographic Heritage Archives, in order to find an appropriate title and an engaging story for their 3D video game. With the guidance of two lead professors and the support of the corresponding program educators, they managed to develop an original scenario which is described below:

"Vienna 2020. The hero of the game finds in the attic of an old, abandoned printing house, inside a locked chest, a Greek newspaper of 1797 along with the torn pieces of a map. As he reads the newspaper, his eyes focus on the following lines: '...the twelve-sheet Map of Greece created by Mr. Rigas has been published and is sold in Vienna and other cities of his choosing, for the price of three groschen per issue.' At this moment, something magical happens. Our hero travels back to the eighteenth century and is transformed to Rigas Velestinlis. He lands on a vast area of a map of Greece, trapped. As he is trying to figure a way out, he realizes his purpose in life: The creation of Charta and the educational, spiritual, and national awakening of Greeks, strengthening the desire for freedom, democracy, and equal rights.

You must help Rigas escape! Run through the map amongst ancient monuments, historical battles, and mythological heroes, find the secret symbols and solve the riddles to piece together the 12 sheets of the Charta. Live the adventure, face your destiny, and join the pieces of the puzzle in order to win. Learn the heroic life story of Rigas through an exciting time travel."



Figure 2: Screenshots from the 3D video game "Hack the Map: Escaping your destiny through Rigas' Charta", photos: Kostas Diamantis

3. Pedagogical Goals

The main objective of the 3D video game was to highlight Rigas' Charta and to motivate the new generation to reveal its secret symbolisms with the help of new digital technologies. This kind of rare and valuable material is usually stored in closed libraries, in strictly guarded areas, on locked shelves and cabinets, for reasons of security, maintenance, conservation. Access is therefore difficult for the average user. Furthermore, there are only few references to Rigas' Charta in school textbooks. Thus, the fact that the design and the development of the game was implemented by students was a very challenging parameter for the entire educational program.

The pedagogical goals to be achieved by the school teams were set on two levels: firstly, as creators and secondly, as users.

The creators of the 3D video game were expected to:

- Learn about the heroic life and the revolutionary personality of Rigas Velestinlis
- Enrich their knowledge about the Age of Enlightenment, the ideas, influences and effects
- Learn about the history of map creation in the past
- Study the iconographic details of the Charta
- Realize how the symbolic language of the map, old or new, can be used to transmit various kinds of information, form ideas and opinions, discard stereotypes and prompt to action

- Combine distinct scientific fields, talents, skills, and technologies in order to synthesize a cooperative digital project
- Conduct historical research and get in touch with primary sources, old maps, and archival material
- Get acquainted with innovative digital tools and techniques
- Collaborate, cooperate, and communicate with their classmates and their professors, set targets and timely complete them
- Visualize ideas by using their knowledge and imagination, in accordance with new digital technologies and contemporary communication practices.

The users of the 3D video game were trained on:

- Learning about Rigas Velestinlis' purpose in life
- Learning about the twelve (12) sheet map he created in 1796–1797 in Vienna
- Identifying twelve (12) symbols on the Charta
- Solving twelve (12) riddles and revealing the secret messages Rigas wanted to transfer to the Greeks
- Helping Rigas to escape his destiny and unite the pieces of his map, spreading the seeds of freedom and justice for all the enslaved people
- Having fun while acquiring new knowledge.

It has been observed that there are a lot of benefits of using museum collections in learning, with a particular focus on using object-based learning (OBL) to support student learning of 'threshold concepts' and coping with 'troublesome knowledge'. Working with historical objects in education, enhances and makes the learning process more effective. OBL offers an interactive experience for students, challenging them to critically address a variety of topics, interacting with each other and focusing on the subject (Hannan et al., 2013). It has been established that 'object-handling has a long-lasting effect and relationship with memory, more so than text-based learning often has' (Romanek, D. & Lynch, B., 2008, p.284). Biggs explains that 'the more teaching and learning activities tie down the topic to be learned to multiple sensory modes, the better the learning' (Biggs, 2003, p.80). The above learning approach mediates and enhances learning, facilitating the substantive and in-depth understanding of a cognitive area (Freeman et al., 2014) leading to a long-lasting effect and relationship with memory, more so than text based handling often has. (Romanek, D. & Lynch, B., 2008, p. 284).

The aforementioned effect is amplified and becomes a novel experience when it is mixed with Game-Based Learning (GBL), in which computer game mechanics (such as a point system, reward system, leaderboards, competitive play, achievements etc.) are adopted in a virtual learning environment constructed by educators. Such methodology motivates further, encourages problem-solving, and strengthens understanding (Gee, 2005). GBL is not meant as a replacement to the traditional teaching methodology but rather as an attractive alternative in order to motivate a younger audience, already familiar with technology, to learn and interact with otherwise difficult to understand topics (Papadakis & Kalogiannakis, 2019). Research indicates that there is a direct association to a student's in-game performance to their decision-making skills that contribute to a positive response to the learning process (Squire, 2006).

Moreover, during this educational program we implemented a Project-Based Learning (PBL) instructional approach, giving students the opportunity to develop skills needed in a modern environment and improve their knowledge through projects that encounter real-world challenges and problems. By applying this non-traditional teaching model, the participants worked on concepts and ideas collectively, divided in small groups for discussions and brainstorming, in order to result to the best solution to each issue or dilemma. This active mode of teaching extended learning beyond the classroom, connecting intellectual inquiry to lived and felt experience. In addition, it provided innovative personality development, transforming the participants from passive consumers of technology to active contributors and linking education with entrepreneurship.

4. Methodology

The methodology of the game creation consisted of the following six (6) stages.

4.1 Stage 1: Research and collection of material

In this stage, the educators prepared rich educational content regarding the Age of Enlightenment, Rigas' life and works and the creation of his Charta. Thematic videos, demonstrative scenarios, bibliography, worksheets and other educational resources were delivered to the school professors, in order to encourage, inspire and

support students to the search and in-depth study of the main topic. All the relative material was uploaded to an open access educational platform, Classroom, aiming at providing students and professors with complete and more direct services.

4.2 Stage 2: Theoretical seminars inside a historical library

In the context of the educational program "Hack the Map" the school teams had to visit the Onassis Library and participate in a series of lectures (3 hours) on History of Cartography, History of the Neohellenic Enlightenment and Rigas' revolutionary activity during that period. Furthermore, the participants had the opportunity to observe and be inspired by an original copy of Rigas' Charta, which is the main exhibit of the library. Finally, they could ask questions and receive answers by a specialized team of educators (historians, documentarists, cartographers, geographers, researchers, visual artists) who were also involved in the event.

4.3 Stage 3: Scenario building

After the theoretical briefing the school teams had two weeks to decide on a title and prepare a short script for their 3D Video Game, making the best use of the educational material available. The main concept should engage and motivate the user to enjoy their own digital creation.

4.4 Stage 4: Selection of twelve (12) stories

Rigas intentionally incorporated in his map symbols derived from the rich classical and European cartographic and literary tradition (Livieratos, 2008, Pazarli, 2014). This rich thematic material was the basis to create the 12 questions of the game (Figure 3). Following this, an initial selection of twelve (12) stories took place, prioritized with emphasis on their educational value, e.g., the Female figure on the forehead symbolizes the basic principles of a new State (justice, equality, independence, reason, quality education, toleration, fraternity), the Ancient Greek theater is connected to the liberating power of Art, the Naval battle of Salamis or the depiction of the battle between Hercules and the Amazon is a metaphor of the ongoing battle between the Greek democratic spirit and Asian despotism, etc. (Figure 3). The selected stories were accompanied by twelve (12) riddles which the players were asked to solve, in order to collect the twelve (12) sheets of the map and complete the puzzles of the Charta. This way, students were intrigued to re-approach Rigas' life and learn how these stories and myths relate to the ideals of Revolution and Freedom.

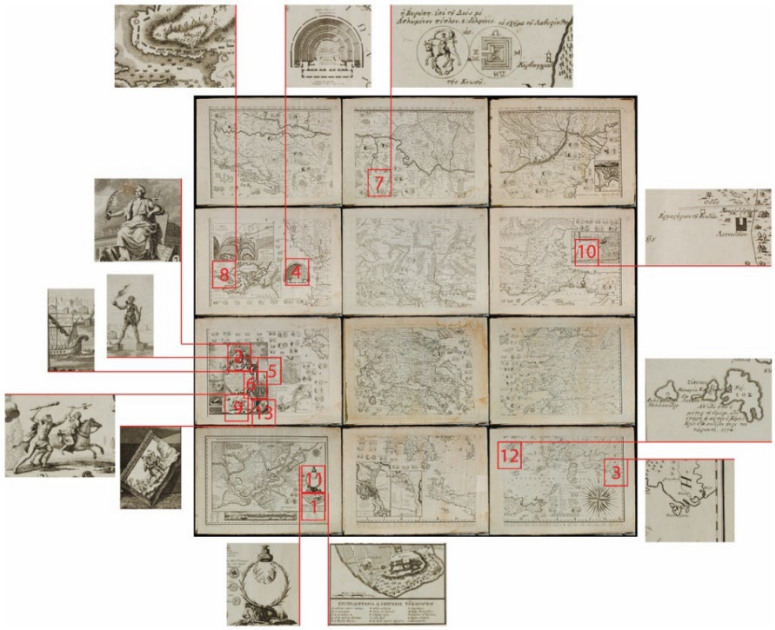


Figure 3: The twelve points of interest and the relevant details, upon which the questions of the game were based: 1. Constantinople 2. Female figure on the forehead 3. A sunken city 4. Ancient Greek theater 5. Colossus of Rhodes 6. Ancient trireme 7. 162 ancient and medieval coins 8. Naval battle of Salamis 9. Hercules and Amazon 10. Ancient Olympia and the Olympic games 11. Sleeping lion 12. Ios island and the tomb of Homer, photo: Maria Pazarli

4.5 Stage 5: Selection of technological equipment, tools, programs

For the creation of the game application, the following equipment was selected:

1. Hardware
   - A laptop for every student; each laptop had a wired connection with access to a shared folder
   - Free internet connection
   - A projector connected to a laptop for the instructor
2. Software
   - Autodesk 3ds Max 2016 educational edition: a software used to create 3D models, complete with textures and animation and is one of the most used tools in the games and VFX industries
   - Unity 3D 2017.3.1f1: an advanced computer game engine that combines all the multimedia elements into a final app or game for various platforms, such as web, mobile, PC etc.
   - Gimp: a free software with a wide array of tools used to edit 2D still pictures and create images and textures
   - Openshot: a free video editing software that can combine and animate 2D elements and effects, producing a video file
   - Chrome: an advanced web browser used for accessing material and testing
   - Audacity: a free software used for audio mixing and editing

4.6 Stage 6: 3D Video Game Implementation - synthesis

The 3D video Game implementation was implemented during three (3) workshops (3 hours/each) which took place in the school computer laboratories and in the premises of Onassis Stegi. There, the students learned the basic principles of game design, level design and gameplay design. In parallel, they were trained in 2D and 3D graphics creation, basic coding via simple scripts, and animation techniques.

More specifically, an introduction was made to the 3D modeling software 3ds Max, following the creation of a simple 3D object for each student, representative of each of the twelve questions of the game. After locating and recognizing the various symbolic depictions and the hidden myths and stories they represent, the students were asked to choose an element to demonstrate how to convert this into a 3D object and build the basis of each of the twelve (12) questions. The next steps would be to import the objects into the Unity game development platform, demonstrate the engine's interface and mechanics, as well as to learn some basic world-building functions and in-engine modeling, animating, scripting assets and effects, such as particles. Animations that would play on a loop were created for most stories with random offsets in order to enrich variation whilst keeping the project optimized for mobile devices as well. Scenes from the Charta were used in some instances and were brought to life by animating the separate elements in 2D or by animating a 3D skeleton; such an example is the scene with Heracles and the Amazon (Figure 4). For certain stories, 3D models optimized for mobile usage were created and exported with custom animations into the Unity 3D game engine. The final material and texture setup took place inside of Unity, with mobile-optimized materials as well for maximum device compatibility. Animations were either created entirely inside of Unity 3D and were initiated via code (some simple geometry objects, such as the coins), or they were imported from the 3D modeling software. A background music track was applied throughout the application and various sound effects per riddle were created and triggered via scripting, as well as narrations for certain events, using the Audacity software. Some additional effects, such as particle effects, were created in order to depict flames or dust for example. Finally, some graphic elements were designed using the Gimp software for the presentation of the app whilst maintaining a unified aesthetic look.

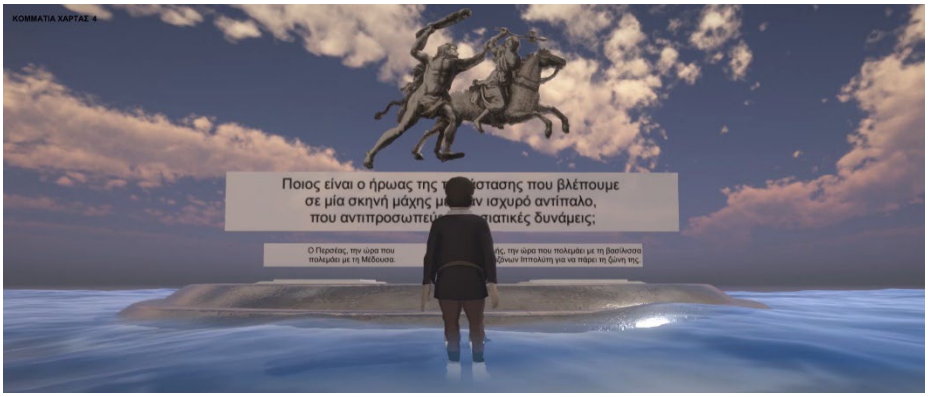


Figure 4: Heracles and the Amazon, source: Hack the Map video game, photo: Kostas Diamantis

All the above were combined into a single project so as to have access to all twelve questions in a game primarily built for Windows 10 devices but also compatible with Android devices. All questions and answers derived from the provided educational material and by examining and exploring the original Charta. Through this innovative educational activity, the students managed to build a 3D 'escape room' with various trigger points in a digital environment, experiencing the game developing production process from start to finish while producing a short serious game inspired by Rigas' life. (Figure 5)



Figure 5: Rigas in front of some puzzle questions, source: Hack the Map video game, photo: Kostas Diamantis

Regarding the game mechanics and the visuals, a unified artistic look was chosen to successfully combine material from various sources while keeping a common aesthetic and achieve better device compatibility. A third-person camera was chosen to both empathize with the main character but to also facilitate the riddle-solving mechanisms. Furthermore, the design of the game itself aimed to reward and not punish the player; to that end an incorrect answer would not have a negative impact on the user. A capture video of the 3D Video Game was uploaded on the Classroom educational platform.

5. Assessment

In order to evaluate the pedagogical value of the educational program and the 3D Video Game, a combination of anonymous questionnaires, direct feedback, reflection, and observation was performed both at the end of each session and after the completion of the series of four workshops. Positive commentary was received by all participating parties (students, professors, educators), with emphasis on the structure, originality, quality, educative value it offered being an interdisciplinary initiative.

According to the anonymous questionnaires, the assessment results were the following:

1. The implementation of the educational program was considered excellent as there was direct communication and facilitation from the organizers and took place inside venues where all the required technical equipment and resources were available to each participant.
2. The structure exceeded the expectations created by the program announcement as beside the scheduled training sessions, the educators provided online documentation and support, in order to help and assist school teams further develop their digital projects.
3. The content was characterized as inspiring and innovative as it combined various cognitive fields with advanced technological tools. Most of the participants answered that they got in touch with new ideas and new information and learned new digital practices and techniques through this experiential educational activity.
4. The lecturers and instructors were assessed as adequately prepared on the topics they presented, effective in transferring knowledge and open to dialogue, fostering an ambience of collaboration and participation. The presentations were considered very inspirational and the provided source material very detailed and challenging in a manner that reinforced creativity, imagination, and ingenuity.
5. The participants enjoyed most the cooperation between people with various interests, the new knowledge, and digital skills they acquired, the fact that they became creators and not consumers of technology and the different perception they gained regarding the lessons of history and geography. On the other hand, they liked least the considerable amount of time they needed to spend on this demanding project, the high degree of difficulty faced and the great effort they had to make in order to succeed their goal.
6. The 3D Video Game created was tested by the educators and the classmates of the school teams and the feedback was very positive. The quality of the game was satisfactory and the user experience very pleasant. It was easy to play, and its educational purpose was simple and clear. The questions selected for the puzzle game motivated the user to seek and learn, strengthening participation and engagement. Visualization helped in understanding difficult or abstract concepts, especially for visual learners. The basic principles of constructive learning, experiential learning (ExL), and discovery learning were combined and delivered through a rewarding system, which greatly encouraged the educational process.
7. In general, the participants were very contented and proud with the digital project they managed to complete, and they were willing to participate again in relative educational events. Also, they noted that they would be very pleased if such kind of activities were incorporated in the main high school program of studies in Greece.

6. Conclusions

“Hack the Map: Rigas’ Charta” was an interdisciplinary educational program combining the fields of museum education, history, geography, and cartography with advanced technological tools. The implementation of digital projects, inspired by a cartographic document of the eighteenth century, was a collaborative activity, that developed student’s personal qualities, enhanced participation, encouraged original thinking, and promoted positive behavior, trust, and contribution amongst them. This contemporary learning approach created an attractive classroom atmosphere and set the basis for the establishment of a new educational model that would give students the required skills in order to compete effectively in the twenty first century and face the challenges of the future.

Although the program was rather difficult and attracted students with different interests, experiences, perspectives, talents, and needs, it managed to unite them under a collective effort due to the project’s demanding nature, triggering Project-Based Learning (PBL). The use of different learning materials and resources provided by the Onassis Library and the Cartographic Heritage Archives, allowed students with various principal learning styles to understand information while boosting their imagination. Moreover, the conception and creation of the digital works gave the students satisfaction, self-esteem, and the freedom to discover their capabilities and individual potentials, promoting dialogue and interaction. Due to the novelty of the concept, this educational program contributed to the cultivation of many different abilities of the participants, including ‘soft skills’ such as understanding, empathy, and communication. Also, learning was fostered by multidimensional interactions between students and their professors, improving their relationship and encouraging the exchanging of ideas.

In addition, this educational activity contributed to the students' positive association with the Onassis Library and its exhibits, and to the formation of a high-quality visitor experience. Through the Object-Based Learning (OBL) approach, students had the opportunity to observe and interact with rare cultural objects, artworks, books, and archives, learn about their protection and conservation and use tools and methods drawn from different disciplines. The adoption of an open access policy for a space full of rare cultural materials amplified the creative expression of the participants and produced interesting associative connections between the theoretical lessons and the material culture, aiding the cognitive process and enriching the learning outcome.

The 3D video game "Hack the Map: Escaping your destiny through Rigas' Charta" strengthened the emotional involvement of users with a historical document and cultivated a positive attitude and enthusiasm towards the learning process, enriching the content of history and geography lessons and creating awareness on cartographic cultural heritage using innovative technical tools in education. The need to devise new teaching methods that appeal to demanding students, in combination with the usage of digital games, led to the adoption of gamification as a learning methodology, focusing on disguising an existing learning process so that users perceive it as a game (Landers, Auer, Collmus & Armstrong, 2018). The gamification approach was successfully implemented in the Rigas' Charta 3D video game, encouraging creative thinking, allowing discovery learning, giving the user a feeling of surprise and excitement, and promoting diversity in education by creating opportunities for students to develop new and different learning styles. The importance of this approach focuses not only on the reward mechanics (Kapp, 2012), but also on the interesting combination of physical and virtual worlds, the immersive mixed reality experiences, the satisfaction of the unexpected, and the joy of discovering hidden symbols and meanings. Finally, the educational program "Hack the Map" intended to bring to light a significant historical document, to animate it, and to motivate the next generation to reuse and reinterpret hidden treasures of the Greek cultural tradition through new technology applications and visual art creations.

The success of this innovative educational experience led to the development of an augmented reality (AR) application entitled "Rigas' Charta", available at Google Play for Android devices (Figure 4). The application was the 1st Runner Up in the Best Use for Fun Category of the 2021 Digital Humanities Awards. Thanks to the positive outcome of the "Hack the Map" program, for the running school year (2020–2021), a National Student Competition was also organized, addressed to all Secondary Schools of Greece with remarkable results in the category of 3D Video Game.

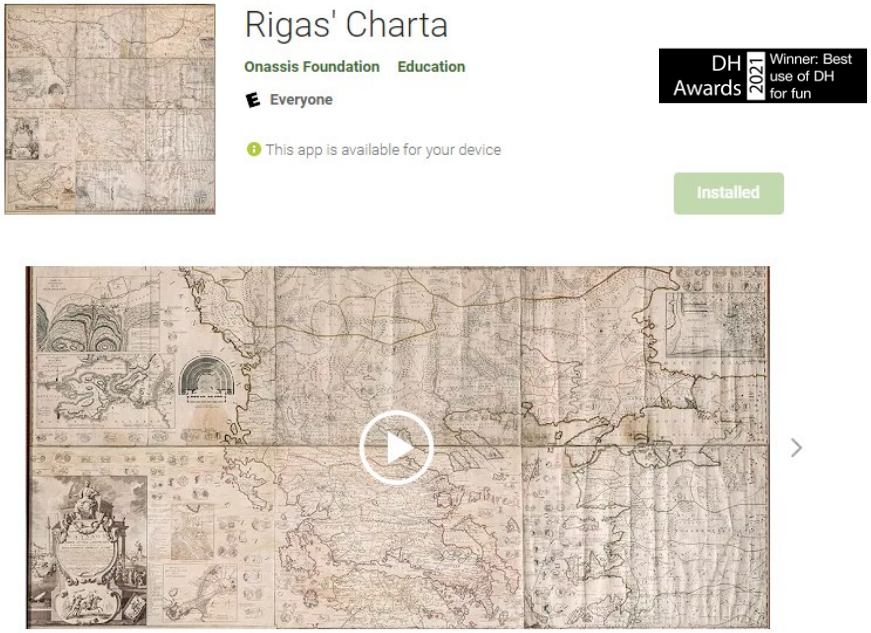


Figure 6: Rigas' Charta, AR application, source: Google Play, photo: Kostas Diamantis

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A Custom-Made Board Game to Familiarise Primary School Children with Atoms

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Abstract: To discover the link between the abstract concept of atoms and the macroscopic material world is often seen as one of the key challenges for new students in chemistry. Failing to make this connection results in low student grades, little interest, and eventually small numbers of graduates in chemistry or related disciplines. Science education research approaches this challenge by designing and creating new learning experiences and curricula for children without any prior knowledge about atoms. One promising approach is to introduce atoms and/or sub-microscopic particles in late primary school, such that children can start making connections between the macroscopic and the microscopic world. In this paper, an educational, custom-made board game that combines science content and fun for primary school children is presented to accomplish this difficult task. The board game features cooperative gameplay for 2 to 4 players, simple strategic elements, and play time between 20 and 30 minutes. Intrinsic integration of the learning content was the leading design idea and, as a result, concrete associations between sub-microscopic particles and macroscopic events related to material hardness lie at the core of the game. Another pivotal criterion was that the game is fully playable for children at home, like other board games, or in school lessons. This contribution, therefore, discusses: (*i*) how the game works, (*ii*) the essential design elements of the current game from a designer's and educator's perspective; and (*iii*) the basic atomic concepts which could be facilitated by playing the game. Preliminary play tests suggest that players, or learners, believe the game to be fun, and appreciate the balance between elements of strategy and luck. In summary, a compact, playful activity could trigger children to think of hardness of solid materials as a property that emerges from the strength of interactions between atoms. Such a change in conceptual thinking could in turn ease students' pathway for future chemistry education.

Keywords: board game, atoms, primary school, game-based learning, particulate models, conceptual thinking

1. Introduction

It is widely agreed upon in chemistry education that atomic-molecular theory (AMT) is one of the key concepts necessary to achieve comprehensive understanding of the nature of matter (Gillespie, 1997). When and how AMT should be first introduced in school has generated debate, and some science educators argue whether the teaching of AMT is too complex for primary school children (Fensham, 1994; Wiser and Smith, 2008). However, a series of recent studies provides evidence that children in primary school can indeed grasp aspects of AMT after formal teaching interventions which cover factual knowledge about atoms (Adadan and Ataman 2021; Donovan and Haeusler, 2015; Haeusler and Donovan, 2020; Baji and Haeusler, 2021). Evidently, the (formal) teaching interventions for a coherent learning strategy for AMT must be carefully designed and often face practical difficulties. Firstly, they require trained teachers and plenty of new learning material. Especially, primary school teachers trained in aspects of AMT are scarce since chemistry is not part of pre-service teachers' education. Secondly, schools often want simple, ready-to-go learning materials which connect to themes of current curricula and fit easily into streamlined school timetables. Therefore, novel, compact, and attractive activities informed by educational frameworks for pupils are highly desired, and educational games seem suitable for this purpose.

Although digital games are dominant in research on games for learning, various factors make it difficult to deploy them in classrooms, such as administration and development, teacher expertise and workload, but also the cognitive demand on students. This is typically not the case for non-digital learning environments like board games as they are often compact, self-explaining, and rather inexpensive (Naik, 2014). Moreover, board games have already been reported as valuable learning tools, for example, in various domains in medicine, or when teaching aspects of the solar system (Bochennek et al., 2007; Kirikkaya, Işeri, and Vurkaya, 2010). Thus, a board

game could constitute a practical solution for teaching atoms, an unfamiliar concept for primary pupils and teachers alike.

2. Goal of this research

This work presents a custom-made board game which also respects curricular pre-conditions (Figure 1). Our previous experiments showed that children have an intuitive notion of which materials are hard or soft (data not shown). Thus, the game aims to acquaint children with the idea that atoms (*i*) are building blocks of macroscopic objects, and (*ii*) different atoms can form different bonds between them, inducing different levels of hardness in macroscopic objects. From a cognitive perspective, this directs towards thinking of matter as being *particulate* (Wiser and Smith, 2008).

First, the game will be explained. Then, the design process will be outlined from two perspectives: one from educational game design and one from educational theory. The former summarizes and explains the set design criteria, and describes how the board game is inspired by popular commercial board games and builds on established board game mechanics. The latter describes guiding thoughts about how atoms are taught to children without prior knowledge. The most essential elements from both perspectives will be then discussed. Lastly, basic atomic concepts which could be found in children's conceptual thinking after playing the game are suggested by the authors.



Figure 1: The main board with its 5 stations (centred), atom cards and boards for dice and scoring (top), and two exemplary challenges (right)

3. Game description

The board game *Material Monsters* (concept name) is a cooperative resource management game for 2-4 players intended for children in late primary school (age 10-12). The goal of the game is that all players together pass 6,

9, or 12 challenges, for 2, 3, or 4 players within 7 rounds, respectively. For each successful challenge, a corresponding token may be placed into the scoreboard (Figure 1, top).

To pass a challenge, the indicated minimum or maximum dice value must be met when adding up two different dice rolls: *atom* and *bond*. All challenges are related to hardness or softness, for instance, that a monster needs to withstand the fall of an anvil (Figure 1, bottom right). All dice roll differently high, and what dice can be taken depends on which atoms and bonds are placed in the back side of the monster tiles. Players will have to use different combinations for different challenges. There are three kinds of atoms (blue, green, and red), and two kinds of bonds (thin and thick). The red atoms can potentially have two thick bonds, the green ones only one, and the blue ones can only have thin bonds (thin bonds also fit into slots for thick bonds). To take a corresponding dice, a monster needs to be equipped with at least two of the same atom and bond tiles. The only exemption to this rule is that monsters with two atom slots only have one bond slot, so only one bond tile is needed. To start a challenge, all atoms and bond slots need to be filled. However, some challenges require a die roll lower than the indicated value. In that case all bonds may be skipped. It is not allowed to have partially filled atoms or bonds (Figure 2).



Figure 2: Examples for atom and bond placement: the left results in dice for red atoms and thick bonds; the right results in a dice for blue atoms and thin bonds

During the game, the main steps to start a challenge are: (1) scanning the monsters, (2) installing atoms and bonds according to the rules above, and (3) attempting the challenges. All steps take place in different stations, and players have three movements per turn to move between them. The five stations are: (1) one for new monsters to spawn [Entrance hall], (2) one to scan and flip the monster tiles [Scan station], (3) one to insert atoms and bonds [Installation hall], (4) one to receive atoms and bonds for the inventory [Atom slot machine], and (5) one station to attempt challenges [Challenge hall]. After every player had his/her turn, a round ends. Since the next two challenges are visible, the players should discuss the team strategy about which monster attempts which challenge, and which atom and bond tiles might be suitable for each challenge.

In the following example of a two-player game, the course of a potential round is outlined (Figure 3). Player green is first and player red is second. The green player could first move to the Challenge hall with the left monster (1). There, this player could attempt the upper challenge. Since there are two blue atoms and no bonds at all, it is likely to roll rather low. This player could also trade items with player red since they are in the same room. Then, player green could go directly to the Entrance hall to pick up the next monster (2) and bring it to the Scan station for the next round (3). Player red could start by moving to the Installation hall to fetch the right monster which is already filled with red atoms and a thick bond (1) and then go back directly to attempt the upper challenge (2). Finally, player red could stock up his/her inventory by gathering more items with the atom slot machine (3).

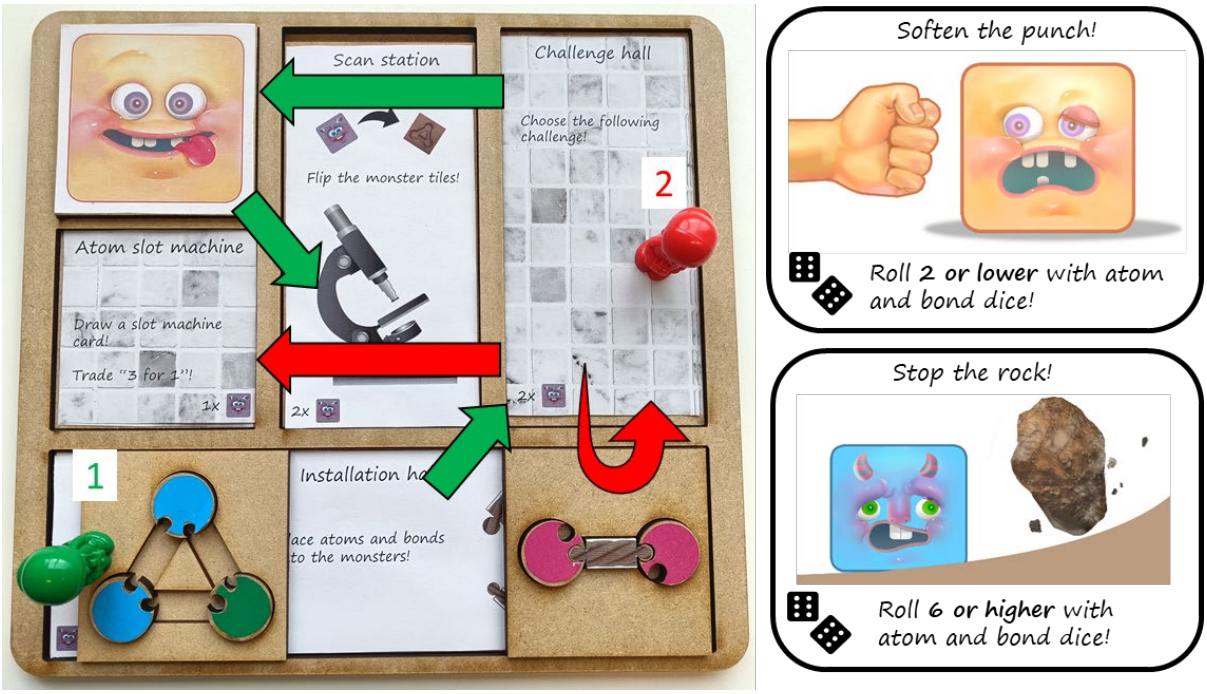


Figure 3: Left: a potential round in a two-player game; right: two challenges of the game

4. The design process

The design process can be seen from two perspectives: one from game design, and one from teaching chemistry. As such, there is an innate difficulty to balance educational content and play, which is pinpointed by an exemplary user review: "For educational purpose I would give this game 8 points. But if I rate it as a board game then I cannot give it more than 6 points" (Staudt Willet et al. 2018, p. 501). Thus, both perspectives show how the current game was designed to achieve learning and fun.

4.1 Influences from educational game design and commercial games

Fundamentally, the concept of 'intrinsic integration' was used as a leading idea to facilitate the balance between educational content and play. Intrinsic integration means that the learning content must be embodied within (*i*) the most fun elements of the game and (*ii*) the structure of the gaming world and the player's interactions with it (Habgood and Ainsworth, 2011). Besides this leading idea, the following other design criteria were set: the game should (1) be cooperative, (2) include strategic elements, (3) encourage communication between the players, and (4) be playable within 20-30 minutes. Each of the set criteria was developed to benefit potential learning for the player. The first three criteria mainly encourage meaningful conversations about the potential take away. If players argue and discuss among each other how available resources are put into place, it is likely they will remember these discussions afterwards. This claim will be validated if a final evaluation reveals successful 'intrinsic integration' of the learning content. The fourth criterion was set to ensure the game stays compact and can be practically played in a school lesson. Having established the leading idea in addition to four other design criteria, it should be outlined how the actual in-game mechanics were derived. That is to guide scientists with little design experience, who are motivated to create other sophisticated games that support players' learning of science concepts.

To initiate the design process, the online portal boardgamegeek.com, and the Dice Tower and its YouTube channel were screened for commercial, non-educational and cooperative board games for children. However, the board games *Forbidden Island* and *5-Minute Dungeon* gave the most impactful inspirations for *Material Monsters*.

In *Forbidden Island,* players have four actions per turn to capture all required treasures before the island, composed of separate board tiles, sinks. Players can cross tiles and have actions, depending on their special class abilities, to achieve this collaborative goal. This game shows several parallels to *Material Monsters*. Similarly, in *Forbidden Island,* players have three movements to contribute to a bigger cooperative process, which is scanning and equipping the monsters to finally attempt challenges. The board similarly consists of different stations/tiles,

and the joint objective needs to be achieved within a certain time (counting the rounds). Further, information cards are part of both games to remind players of actions/movements and what can be done in each island tile/station.

In *5-Minute Dungeon*, players fight different sets of monsters with different symbols in 5 minutes. They do this by placing offensive cards matching the symbols of the top pile monster card. Players must argue fast who has the required symbols and play cards accordingly. Once the necessary symbols are matched by all played cards, a monster is defeated. This game gave major inspirations towards preliminary versions of *Material Monsters* for attacking and defence mechanics with atoms, but also to the current version. The concept that monsters are featured in a child-friendly (battle free) design remains unchanged.

On boardgamegeek.com, both *Forbidden Island* and *5-minute Dungeon*, have a medium or high overall rating and a low complexity rating. Moreover, both games are cooperative, can be played within 30 minutes and suit our targeted age range. As such, these well-rounded games gave major inspiration to the design of *Material Monsters* and deserve credit.

Thus far, it was illustrated what game design criteria were set and how in-game mechanics were derived. Now, these criteria and mechanics need to be embedded in the theoretical educational framework to teach atoms.

4.2 Influences from educational theory

In previous tests, primary school children ranked the hardness of materials in a similar order, with steel being harder than stone or wood (data not shown). So, it is assumed that children have an intuitive notion about which materials are hard and which are soft. Although they can describe how to test hardness of materials (e.g., smashing it with a hammer, applying some kind of external force), they cannot explain *why* materials are hard or soft because they are not familiar with the microscopic world. So, we intended to provide a playful activity which should facilitate a meaningful explanation of the hardness of solid materials. In simple terms, the nature of the bonds between different atoms or groups of atoms determines the hardness of solid materials. For a more detailed explanation of hardness, Broitman (2017) provides a critical overview. Thus, the educational goal of the game is to acquaint primary school children with the idea that atoms (*i*) are building blocks of macroscopic objects and (*ii*) the strength of bonds between atoms results in different degrees of hardness of materials. Currently, there is no defined way how to best teach concepts of atoms to young learners that have no prior knowledge of atoms. Generally, it is crucial from an educator's perspective, to avoid teaching misconceptions about atoms. For instance, it has been reported that students erroneously attribute a macroscopic property of the material to the atoms which make up the material (Ben-Zvi, Eylon, and Silberstein 1986). This consideration directly influences visual aspects of the game.

Scholars argue that intermediate atomic models could function as a stepping-stone to acquire more sophisticated ideas about atoms later on, instead of teaching what is scientifically accepted from the beginning (Johnson, 1998; Wiser and Smith, 2008). Such models are, for example, what Johnson and Papageorgiou (2010) describe as Model B, "the particles are the matter, but they have a macroscopic character", or Model C, "the particles are the matter. They do not have a macroscopic character". Further, Model C is described as "[…] properties of state are collective. Particles are drawn and said to be the substance. The properties of a state are seen as collective properties of particles." (Johnson 1998, p. 399). The current design incorporates this idea by framing that there are different atom types which have different capacities to have bonds. It does this by representing atoms as tiles with different colours and big or small puzzle-like slots for the bond. Regarding the bond tiles, two types are used in the game: thin and thick, in the form of small cord shapes (Figure 3). This is to qualitatively represent a weak and a strong interaction and to strengthen the idea that different factors affect the hardness of a material. In this way, it could be concluded that the capacity of a material to withstand external forces depends not only on the type of atoms that compose a material, but how the atoms interact collectively. Overall, this design was deemed to be compatible with Model C.

If primary school children have an intuitive notion of hard and soft materials, the game could direct them towards *particulate* thinking when they discuss with each other what types of atoms might be sufficient for the next challenge. So, this idea is directly connected to the communication criterion.

Lastly, some notes on terminology should be made. From a chemist's perspective, the most important 'stages' of sub-microscopic building blocks of matter are atoms and molecules, and their interactions are usually

categorized as intra- and inter-molecular forces (e.g., covalent bonds or Van der Waals forces). When using the more generic term 'particle', it is suggested that children think in a scale of tiny dust particles (Jakab, 2013, p. 1310). In this game context, we prefer 'atom' as the term more likely refers to a single entity (unlike 'molecule' at this scale), and 'bond' which is, chemically seen, a rather generic term.

5. Discussion and preliminary results

The discussion comprises two different dimensions. First, it is discussed whether the game addresses the set design criteria, then explicit design decisions are revisited with regard to the avoidance of misconceptions. Finally, preliminary results should indicate which elements were deemed as fun, which leads to a short outline how the game will be used in future studies.

5.1 Design criteria

The game underwent several (re-) design and test sessions with experts from game design and chemistry education, with 'intrinsic integration' as a leading idea (Habgood and Ainsworth, 2011). In previous versions of the game, structures of atoms and bonds served as upgrades of the strength of weapons, and also as a proxy for defence values. This set up was not pursued since increasing a defence value using different atoms or bonds does not intuitively suggest that a monster becomes harder. Moreover, attack/defence values are upgraded by all kinds of elements in other games such that atoms seemed to be replaceable. In the current version, any fighting mechanic with atoms and bonds was replaced by an equip-and-test mechanic of hardness related events with these items. Now, the success of a challenge is more intuitively translated into which atoms and bonds are installed into the monster. Eventually, it was deemed that the current set up fulfils intrinsic integration of the learning content. This claim is supported by feedback from students who reported the scoreboard and challenges with their simple but sufficient art, as well as sticking atoms and bonds together, were most fun. Nevertheless, it remains arguable whether the game does feature 'intrinsic integration' and if games including fighting elements with atoms promote understanding of the composition of materials.

The criterion of being cooperative has been fulfilled as achieving a certain number of challenges is a clear collaborative goal. Of course, it can be argued whether cooperative games have an educational advantage over competitive games (Wouters and Van Oostendorp, 2013). However, this complex, fundamental change in thinking for each player is mostly independent of in-game performance but more related to the amount of interpersonal interaction. Players are dependent on each other by sharing and trading resources, so collaboration seemed to be supported (Hummel et al., 2011; Hung, Young, and Lin, 2015). Regarding the next two criteria, strategical elements and communication, the principal game mechanic is fairly simple, but it is not obvious for a new player which combination of dice poses a sufficient chance to pass a challenge. Although failed challenges remained the exception during playtests, players must become familiar with expectable dice rolls. As such, players argue which of their items are used best for which challenge as they can always choose between two with a third challenge being face up on the card pile. Thus, the strategy and communication criteria are deemed to be met as well.

Lastly, a playtime of 20-30 minutes was partially fulfilled. Internal playtests have shown that players interact - with sufficient atom and bond tokens to start challenges within 20 minutes. However, finishing a full game highly depends on the experience and absolute number of players. In some playtests, the playtime exceeded 40 minutes. This drawback seems acceptable so long as children are exposed to all the intended game mechanics. Moreover, an incomplete game could spark motivation for students to complete the game at home, or during longer breaks in school.

5.2 Explicit design decisions

Finally, it is important to briefly discuss whether the game avoids introducing potential misconceptions about atoms. As mentioned above, some ideas about atoms might hinder students' progress to more advanced concepts (Pozo and Gomez Crespo, 2005). For example, it is cognitively constraining when learners think that substances are made of tiny particles of the same material embedded in a supporting material like air or the substance itself (Talanquer, 2009). That way of thinking also resembles Model A of Johnson (1998). In a previous version of the game, atoms looked like spheres of sponges, stone, and steel (Figure 4). This feature was initially designed to evoke a connection between atoms and materials, as the game did not specify the composition of the monsters. The monsters only acquire hardness through the rolling of the steel die. To avoid the misconception that atoms are small pieces of macroscopic materials, atoms are now given colours unrelated to

familiar macroscopic materials, and each different atom has different bonding capacities. In summary, we expect that the current design has high potential to evoke well-founded ideas about atoms.

Starting to think that the hardness of materials is not inherent (i.e. steel is hard *because it is* steel) but due to invisible building blocks and their interactions is not intuitive but a complex, non-trivial cognitive process (Wiser and Smith 2008, Vosniadou 2019). Thus, it is inevitable that children will need to be confronted with this idea frequently over time. A game or fun activity could provide an optimal opportunity for such kind of learning as it is likely to be revisited.



Figure 4: Tiles for atoms and bonds (left current, right previous version)

5.3 Preliminary results

At this stage, internal playtests with students and pilot tests with primary school children have taken place. Play testers (adults and children) found the challenges, the game's art design, and how to fill the scoreboard as fun and motivating. Besides that, they needed to manage and share resources, gather resources with cards and resolve challenges by rolling dice. This mix of elements seemed to offer a reasonable balance of planning and luck (data not shown). This is supported by quotes during pilot tests. When being asked whether there was something they especially liked in the game, they uttered (translated from Dutch):

Girl (10): I did find it fun and interesting [in general]
Boy (11): I did like to build like that, and yeah, then you could also do challenges like that [...] so I would like to have it at home myself
Boy (11): you only had to see which atom it was and install it like that [...] and I liked that I can choose 3 [referring to atoms]
Girl (12): it was a lot of fun to roll [the dice] and then you were here [pointing to the installation hall] to pick atoms

In conclusion, the game appears to be an enjoyable activity at this stage. Eventually, a player could acquire some basic atomic concepts after playing the game, as suggested by the authors in Table 1. In future studies, using an analytical process similar to that of Stevens, Delgado, and Krajcik (2010), children's utterances after playing the game can be coded to show whether children indeed start to think differently about the nature of materials.

Table 1: Potential basic concepts of atoms after playing the game

Nr.	Basic atomic concept
1	Atoms are spheres
2	There are different types of atoms
3	Different types of atoms have different capacities to make bonds
4	Some interactions are stronger than others
5	Thin/thick bonds represent weak/strong bonds
6	The interaction affects the hardness of the monster
7	The stronger the interaction, the harder the monster
8	Different materials have different atoms
9	Atoms can be mixed in materials

Nr.	Basic atomic concept
10	There are different compositions of atoms
11	The strength of the bond between atoms determines the strength of solid materials
12	The collective behaviour of atoms and bonds determines hardness
13	Hardness, or softness, as macroscopic properties, emerge from atoms

6. Conclusion

With *Material Monsters*, a custom-made board game was created for children to discover atoms and their relationship to material hardness. The game itself and important stages of the design process were presented, and design criteria as well as essential game elements have been discussed from a designer's and educator's perspective. Preliminary results suggested that the game is enjoyable. It was argued that it meets the set criteria. Influences from both design perspectives promise that aspects of particulate thinking can be evoked, but tests with children have yet to confirm these expectations. Therefore, it is planned to conduct game sessions, with pre-, post- and retention interviews with children of late primary school. Moreover, it needs to be shown whether children also want to play it at home, just like other board games, and if they deem it fun. In subsequent iterations, additional components might be added to create a more complex board game. 'Monsters' might be replaced by 'robots' that need to be custom made such that they can make household or work activities more fun or safe as this way of framing might give a more plausible context on why the challenges need to be done in the first place.

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Art for the game was created by freelance artist Pochanun Waenpetch. Icons for the atom picker (installation hall) and the trophy are resources from https://www.flaticon.com. Icons for the microscope (scan station), bond maker (installation hall), and the background for the floor are resources from https://de.freepik.com.

Ludography

5-Minute Dungeon, designed by Connor Reid, published by Wiggles 3D. https://wiggles3d.com/5md/;
Forbidden Island, designed by Matt Leacock, published by Gamewright.
https://gamewright.com/product/Forbidden-Island

Other resources

Boardgamegeek.com, https://boardgamegeek.com/boardgame/207830/5-minute-dungeon;
https://boardgamegeek.com/boardgame/65244/forbidden-island
The Dice Tower, website: https://www.dicetower.com/; YouTube channel
https://www.youtube.com/user/thedicetower

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Mind the gap: The 4M Bridge Between 4E-Cognition and Movement-Based Design

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Abstract: Along with technology trends like extended reality, wearables, IoT, and exergames, new design approaches have emerged, focusing on full-body interactions by actively working with the lived body's capacity to sense, feel, and create. Thus, designers are recommended to use movement as part of the design activity when designing for and of movement, regardless of the targeted application domain. However, designing for bodily experiences is challenging. We have identified a gap of no movement-based design framework available, including the moving body as the centre part and core material of the design processes. We recognise the human body is more than a physical object in the world, but a feeling, perceptualising body, that creates meaning in interaction with the environment. It thus frustrates and challenges us to reach a bodily grounded design process embracing the lived body. A common framework informed by the theoretical aspect of embodied cognition and the practical element of movement design can be a starting point for embodied design research. Recognising these challenges, we see a need for creating a bridge between practice and theory. Based on the bridging concept from Dalsgaard and Dindler, this paper presents a movement-based design framework to bridge the abstract idea of embodied cognition theory with the 4E perspectives of embodied, embedded, enactive and extended and concrete movement-based design practices. We created a movement-based design framework structuring the movement-based methods of different perspectives. The 4M model we propose contains three types of facilitator-mediated methods: 1) Mood-setters stimulating a creative body being, 2) Movement-based design methods for creating immersion in creative bodily activities, and 3) Movement concepts as knowledge and evidence for developing and validating movement artefacts. Besides the facilitator cards, the participants have access to Modifiers that can be used in conjunction with the other methods as creative inspiration for exploring, trying, or performing new movement possibilities.

Keywords: Movement-based design, Embodiment, Design methods, Exergames, Design framework

1. Introduction

Our vision is to make movement-based design approaches and practical movement-based design activities accessible to a broader audience of designers and movement professionals who are not movement experts. But even as sports experts in our design practise, we find it challenging to translate an embodied and movement-based design approach into design practice. Recognising this challenge, we see a need for creating a bridge between practice and theory in movement-based design. Based on the bridging concept (Dalsgaard & Dindler, 2014), this concept paper presents a movement-based design framework to bridge the abstract idea of embodied cognition and concrete movement-based design practices.

When designing "for" and "of" movement, designers are recommended to use movement as part of the design activity and build awareness of the fleeting and immediate movement experience (Schleicher et al., 2010; Márquez Segura, 2018; Elbæk & Friis, 2017). With this, we recognise the human body as more than a physical object in the world. It is a feeling and perceptualising body that creates meaning in interaction with objects, the context, and other humans. As Malinin (2019) argues, creativity must be understood as a dynamic relationship between bodily movement, environment, and cognition. Based on the philosophy of embodied cognition, we, along with other scholars, argue for an understanding of how we can unleash creativity in design processes.

In design practice, however, designing sustainable solutions for and of movement poses a challenge for designers regardless of the target domain (such as technology-driven games, sports performance, physical activity, and fun and enjoyment in physical play etc.). As Segura et al. (2016) state, it can be challenging to design immersive bodily experiences due to the lack of spatial and social context in design activities. It, therefore, requires the designer to facilitate the right mindset by designing the optimal process through choosing and

interconnecting methods to explore embodied movement as a medium of creativity. Therefore, the successful application of movement-based design relies primarily on the individual designer's knowledge and practical movement skills (Svanæs & Barkhus 2020). It requires effort from the designer in planning, facilitating and analysing movement insights. Therefore, the designer must possess both confidence and skills to facilitate and engage in movement-based design (Andersen et al., 2020).

We believe that there is a gap of no movement-based design frameworks available to advance theory-grounded movement-based design practice and with movement as the crankshaft of the design process. In the domain of exertion game design, Müller et al., 2011 have created an exertion game design framework with the moving and active body as one of four elements. However, we believe there is a need for a movement-based design framework with the moving body as the approach's core.

Thus, we want to democratise movement design and unleash movement creativity for engineers, designers, and students and enhance sports and movement professionals' awareness of their core design competencies. The 4M-framework we present bridges abstract theory and design practice through a holistic view of movement-based design, which can be applied across contexts and target domains. We believe in our mission through this embodied design approach to support the creation of more sustainable and engaging movement-based design solutions.

2. Applying a "bridging concept" between embodied philosophy and movement methods

Practical design research happens in the research themes and activities between philosophical, theoretical, methodological, design activity (methods), and the making of designed solutions (Koskinen et al., 2011). A bridging concept bridges the themes and activities, and is a mean for limiting thoughts, supporting a discussion, and planning supported by the intermediate knowledge one has.

Created by Dalsgaard and Dindler (2014), the bridging concept forms an intermediary link in its ability to bridge the gap between an abstract overarching theory and concrete practice. A bridging concept consists of three defining constituents: a theoretical foundation, a set of design articulations, and a range of exemplars that demonstrate the scope and potential of their application. Following Stappers & Vissers (2014) terminology we create a bridge between the abstract level of the philosopher and the concrete level of the designer via our framework.

The framework supports future facilitators and designers who wish to understand the means and mechanisms of creating an immersive process for movement-based designs. Even though it is an inherently unstable and intermediate form of knowledge (Dalsgaard & Dindler, 2014), the framework is meant to support the design process and not hinder it.

3. Approaching Movement Creativity through Radical Embodied Cognitive Science

Designing creatively for and of movement is highly immersed in the personal being of the designer and interwoven into the external world. Thus, applying a philosophical concept that uses a holistic understanding of cognition is preferable. Radical Embodied Cognitive Science (RECS) frames cognition to embrace the brain, body, and the world in a dynamic system (Malinin, 2019). It goes beyond seeing the brain/mind as a computer located in the head disconnected from the environment and sees cognition as a constitution united between mind, body, and the world. A way to understand RECS is by the 4E concept, which involves the body and the body's situatedness in the environment (Newen, Bruin & Gallagher 2018). Each concept within 4E is each intertwined with one another, making the cognition process complex and always embodied, embedded, enactive, and extended.

Embodied cognition refers to the premise that perception and cognition are embodied and impact whole-body interactions with the world. Mental phenomena such as perception, memory, reasoning, language, emotion, and consciousness are constituted and depend on the entire body.

In the concept of RECS, embedded cognition is understood as rooted within a specific context and oriented toward action (Newen, Bruin & Gallagher 2018). Thinking in action is related to how the environment allows focusing on the relationship between our improvisational or adaptive actions and the situation.

Enactive cognition relies on motor activities (action) and sensory perception, and there is no significant difference between acting and perceiving. Enactive cognition is interactive with the biological and nonbiological environment and requires a continual negotiation between the individual and the collective community.

In extended cognition, thinking is understood beyond the body and the mind. Here, physical things in our environments are seen as part of the cognitive system, and we must understand our beings-in-the-world as a connection and a constitution between our body and the world.

Putting this understanding of cognition as a complex process involving the 4E's, "embodied creativity includes creative expressions and processes that emphasize or are generated by the physical body. This view of creativity highlights physical responses within creative practice and is attentive to the influences of space, environment, materials, and the individual's relationships to other bodies" (Griffth, 2021). We view this understanding of cognition as stressing that the state of being in the world should be considered when designing for, with, and of movement in sport, movement, and play. We must consider how to practice design for movement in a social and cultural world, where our bodily engagement with the environment is part of cognition and creativity.

4. The genesis of the 4M framework

We used constructive design research methodology (CDR) (Koskinen et al., 2011) as an overarching approach to structure in designing the framework. In CDR, the creation of a design is founded on both abstract theory and practical and research-based knowledge, and the creation of physical or social artefacts is the key to knowledge production. In our process, we constructed and re-constructed a provisional framework, aiming at encapsulating our understanding of the overall movement-based design process. Our design process was advanced by several workshops, building prototypes of methods cards, building prototypes of the framework, testing movement-based practices, conducting desktop research, and discussing theoretical and practical aspects. We summarise this process three years process in two distinctive phases we call Storming and Symphony. The storming phase consists of an explorative approach for iteratively creating movement-based methods cards and the framework. In the symphony phase, we tested movement methods and the framework and consequences of our decisions.

5. Presentation of the 4M framework

Based on the design process, we have developed the 4M framework as a model for understanding approaches when designing for, of, and with movement in sport, technology, game, and play. The 4M framework consists of four elements of movement-based design activities: Movement modifiers, Mood setters, Movement methods, and Movement concepts (figure 1). The 4M model illustrates a box placed on top of Modifiers that you can use along with the three other types of movement methods. The box' red foundation (bottom) is the Mood-setting. The green movement methods on the left side of the box embrace design methods with a Movement-first approach. The right blue side of the box represents Movement-concepts of knowledge.

The framework is inspired by Karoff (2013) understanding of play as a triad interplay between play media (nouns), play practices (verbs) and play moods (bodily state of being). The framework takes a constitutional stand in movement-based design (Andersen et al, 2020) acknowledging the movement-first approach (Segura 2016) and movement as a medium for different aspects of design activities (Loke & Robertson, 2013), adding specific movement and sport theory and evidence. The framework enhances an understanding of how to create and enrich a movement-based creative design environment. In developing a movement-based design framework we strive for making movement-based methods navigable and actionable in the fields of interaction design, game and learning design as well as in sport & physical activity design. With 4M, we strive for having a medium to gain confidence in using movement in design practice. The target users of the framework are students and design professionals across disciplines such as engineering, design and PE, sports, and movement-health.

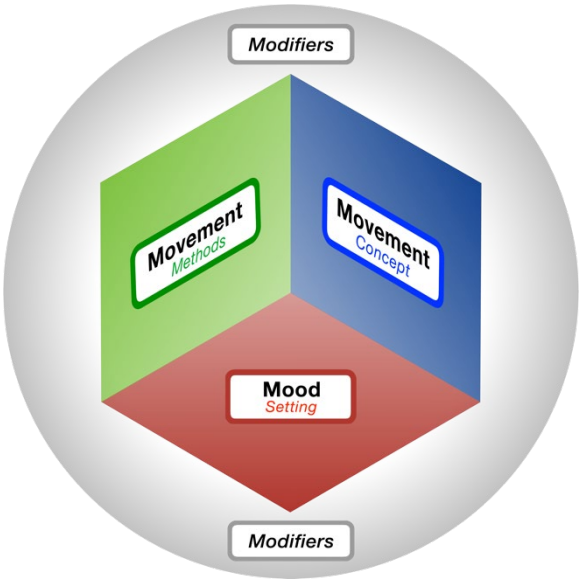


Figure 1: the 4M framework for movement-based design

The four constituents are independent of each other. Consequently, any chosen movement method does not rely on a corresponding mood (setting) or a relevant movement concept. By adding the different constituents, we suggest that a movement-based design practice has different layers and perspectives, and that designers or facilitators must understand and plan design processes recognising these layers and perspectives.

In the next section, we provide a description and examples of the four constituents to give an image of the separate elements and how they guide the movement-based process.

5.1.1 Mood setters

Having movement at the centre of interaction design and as the medium of design, it is our experience that being in the 'right' state of body being is essential for choosing a movement first approach in the design activities and thus practising warm-up like activities. The Oxford Dictionary of Sports Science & Medicine defines a warm-up as typically comprising "mild exercise to raise tissue temperature and stretching" and "to prepare the athlete psychologically".

We propose and classify a variety of warm-up games as Mood Setting. The activities prepare participants physically, socially, mentally, and for movement design purposes, also include embodied creativity training. It embraces activities such as icebreakers, warm-up exercises, team building, and physical technology-supported games (Márquez Segura et al., 2021). We use a typology for making the Mood-setting method identifiable regarding function in the design processes. The typology contains Exertion, Playfulness, Body Awareness, and Creativity. Altogether, the Mood Setting activities are warm-up like energisers with a creative potential. For the participants they that typically take place before the primary design activities and can be applied to energise the design process. Furter the movement methods will be searchable by the duration of set-up time and proposed activity time, proposed number of people participating (social configuration), and material (props) needed.

5.1.2 Movement Methods

Design methods are generally known as a designedly way of working in a design process. Well-known design methods are brainstorming and sketching with the general idea of using primarily cognitive processes. The framework constituent of Movement methods contains design methods, which use movement as a medium to explore, stimulate and activate designers and their creativity in a design process (Andersen et al., 2020). The use of movement as a part of the design process stems from practices such as dance, sport, rehabilitation, and theatre (Höök et al., 2017). It has sparked the emergence of embodied sketching (Segura et al., 2016) and movement-based interaction design disciplines (Loke & Robertson, 2013). We acknowledged the body and movement as a way for designers to engage in design challenges to pursue insights (Andersen et al., 2020).

The Movement-based methods have a specific context-bound design goal. Dividing the methods through how they use movement as a medium to achieve the design goal, we informed by Andersen et al. (2020), further

develop the categorisation of the methods into Exertion, Playfulness, Body Awareness, and Role-Playing. Furter the movement methods will be searchable by the duration of set-up time and proposed activity time, proposed number of people participating (social configuration), and material (props) needed.

5.1.3 Movement concepts

Informing the design, we propose using multi- and cross-disciplinary research-based evidence and theory as a knowledge foundation when designing for and of movement, sports, and interaction technology. Peters, Loke and Ahmadpour (2020, p. 417) define a concept (cards) as "Some tools present chunks of expert knowledge in a manageable manipulable form". Based on different disciplines in scientific areas, we have developed Movement Concepts in the areas of Philosophy of Sports and Movement, Psychology of Humans, Humans in Society, Motor Learning and Biomechanics, Physical Training and Physiology, Sports, Games and Play, and Sports and Movement Technologies. The Movement Concepts includes manageable descriptions of theories, knowledge, and evidence, plus generative questions, and reflective questions to support informative decisions making in the design process.

5.1.4 Movement Modifiers

Movement modifiers include cards and physical artefacts that support, modify, tweak, or disrupt design practices. Informed by Peters, Loke and Ahmadpours' (2020) review, method cards formed as props, fuel divergent thinking as a scaffolding of the design process. The artefacts stimulate physical exploration and creativity when participants use them in design and real-life settings. Engaging and moving with the artefact can be generative for the design activities. Modifiers can also be words or pictures related to a sport, movement, or sports theme, and they are placeholders representing components within a system. Modifiers can tweak movement like, e.g., via cards of movement qualities, types of core movements, movement metaphors, different sports disciplines, play and play elements. Movement can be modified using technologies and game genres and types. Modifying people using personas and constraints. Modifying motives through experiencing movement through different lenses & logics, stances & values, and perspectives of movements.

6. Bridging the framework to practice

We will exemplify the framework from two perspectives: 1) "design *of* movement" in the Creative Acrobatic Body course for sports science students and 2) "design *for* movement" with the HangXRT bodystorming case. For the 4M model in use, we first describe the case then, the concept of the 4M model is related to practice use.

6.1 Case presentation: The Creative Acrobatic Body

The Creative Acrobatic Body is a 3 ECTS bachelor course for Sport Science Students at our local university's innovation track. The students' course task is to create a bodily acrobatic performance informed by or invented from movement cultures of their own choice, e.g., parkour, new circus, creative gymnastics etc. The student's assignment is to produce an informative inspiration video showing parts of the performance and core elements of the process of creating said performance. The course provides students with the knowledge and practical experiences in different acrobatic movement practises. We introduce how embodied creative and playful learning processes unfold within innovation. The course is structured as 1) formalised lectures and 2) practical workshops. Before any practical workshops, the students participate in a lecture-based on the coming practical workshop (e.g., the culture of parkour, gymnastics, parkour, or new circus).

Applying the 4M framework in the workshops, we recognise icebreakers, warm-up, and team-building activities to enhance the participants' mood-setting towards playfulness, trust, and creativity. A Mood-setting activity used was "Follow the leader". In the workshop, we introduced and practised movement creativity based on the structure of the 4M framework by;

1. using Modifiers, physical prompts (artefacts), movement qualities images, and play formats on word-cards as embodied creativity disrupters
2. improvising movement as a Movement method to explore acrobatic movement possibilities
3. using the context and theme knowledge from the formal lectures to reach the design goal as a representation of Movement concepts
4. using music to facilitate creativity and, as such, representing a Modifier (Segura et al., 2016).

The last workshop element was video documentation of a mini-performance for further feedback and reflection on the process of working with embodied creativity.

In their self-guided work, the student applied movement methods such as props and gym equipment experimentation as an emergent movement method represented in the 4M framework.

The workshops and the students' self-guided project work illustrate how both facilitators and students apply the 4M framework and the movement methods, respectively, in their teaching and learning. It includes designing and practising their performance and sharing visual (video) knowledge to inform other potential users' embodied creativity and "design of movement".

Our next case shows the 4M framework's potential focus on designing for movement.

6.2 HangXRT bodystorming through the 4M framework

Segura, Vidal and Rostami (2016) created the workshop HangXRT to design computing technology games that encourage vigorous physical activity and physical fatigue. The workshop's background lies in the knowledge of how physical fatigue resembles what happens with real-world sports, and such a game provides physical and cognitive advantages.

Segura, Vidal and Rostami (2016) succeed in allowing participants to engage in embodied ways of designing supported by an atmosphere of physical and social play. The general idea of the workshop was to utilise the principle of show, don't tell and let the environment become a design resource. The generative workshop approach involved an on-the-spot complex design space of people, technologies, artefacts, and physical elements in a bodystorming session to envision and act through physical activities. The core artefact was the TRX suspension trainer, a piece of equipment attached to the ceiling. Participants hung and moved with, within and around the TRX. Other playful artefacts were provided as inspiration for the participants, and the facilitator instructed them to take turns in their experimental actions with the TRX and the artefacts.

Understanding HangXRT through the 4M framework, we see Segura, Vidal and Rostami (2016) utilise movement methods by placing the TRX at the centre of the room and making the participant experiment with movement through the TRX and the principle of show don't tell.

The participants were encouraged to involve other artefacts to change the perception of the movement and the concept. The group is observed bringing in balls, skateboards, and mats for tweaking the bodystorming process (Segura, Vidal & Rostami, 2016). In doing so, aiming toward physical exploration instead of classic cognitive problem-solving and the artefacts are seen as modifiers supporting this physical exploration. While at the same time recognising the mood-setting part of the 4M framework by addressing the artefacts as playful artefacts.

The Movement-concepts of the 4M framework stem from the participants involved in the process. The participants were experts in physical activity, exertion games and motivation; the theory was the foundation of the design (Segura, Vidal and Rostami, 2016).

The design of the technological solutions for TRX starts with a movement first approach. We show the potential of using the 4M framework to analyse design activities and structure future developmental processes alike.

6.3 Designing with movement – implication, reflections, and recommendations

We for now proceed with our reflections on the bridging of the 4M framework with the 4E theory and we will discuss implications, reflections, and recommendations.

Alongside the sports and movement focused technology trends new design approaches have emerged, focusing on full-body interactions by actively working with the lived body’s capacity to sense, feel, and create. We have to a lesser extent been able to bridge an embodied understanding of cognition and movement-based design approach into practical design activities. We created the 4M framework to bridge the theory of 4E and with this enhance the practical use of 4E creativity (Malinin, 2019). As Malinin (2019) states, based on the 4E, “creativity does not begin with an idea in the head that is subsequently realized; it emerges through interactions with others and artefacts of the material environment”. The 4M framework makes a bridge for non-movement experts and experts to understand and structure movement focused design processes that take into consideration the elements of 4E – embodied, embedded, enactive and extended cognition in both divergent processes and convergent processes of a design process. As 4E operates with an extended form of cognition involving bodily,

material/technological, socio-cultural, and temporal dimensions (Malinen, 2019) the 4M has a Mood setting to promote a forthcoming social-cultural environment.

The embodied dimension of 4E points to the embodied being and thus the mood of your body being will affect the creative potential. As the phenomena of perception, memory, reasoning, language emotion and consciousness are constituted and depend on the entire body. The Mood-setters as warm-up games are drawing on these cognitive phenomena from a movement-based and playful approach striving for loosening up for internal creative potential as well as reaching out for and connecting to fellow participants taking part in the design activities. The Mood-setting activities have affective, social, trust formation, perceptual, cognitive, and physiological outcomes. As such warm-ups as embodied games show potential toward unlock innovation, creativity, and intelligence (Segura et al., 2021). The Mood-setting we interpret as having an embodied metaphorical creativity training dimension. Thus, drawing on how movement may enact embodied metaphors. It also draws on that walking and particularly free walking improves divergent thinking (Malinen, 2019).

The Movement methods involve bodily actions, and the modifiers give access to a wide variety of material and technological artefacts. Thus, for Segura (2016), the embodied ideation is realized in the participants' lived physical and social life world. The holistic approach that Segura is describing in most aspects builds on the potential use of 4M and primarily on perception-in-action as defined for the enactive perspective of the 4E model and makes a movement first approach by Segura (2016) actionable. The 4M framework we believe used in an open and situational adaptive way will be part of forming design as creativity-in-the-wild (Malinin, 2019).

In developing the framework, our focus was on design for movement and design of movement as described in the two cases. Although we recognise the framework is more than of and for movement in design with movement. We are convinced the framework can also be used in numerous design settings, e.g., bus stops, supermarkets etc.

Conceptualising movement as a medium that stimulates, forms or catalyses insights within the design process, we reject a focus on how much movement. Instead, we advocate for how movement promotes energy and catalyses insights, we argue for design activities not directly related to design for and of movement. For this, the 4M framework could be relevant for designers and non-experts of movement to use movement-based and embodied design approaches.

7. Concluding remarks

Authentic movement-based design requires sympathy with the movement, and the context, establishing a forthcoming interaction between the participants, fostering a creative body being and thus enhancing positive, creative moods among the participants in the co-design processes. The 4M framework is based on the prerequisite that the environment is an umbrella term to describe both human-specific environment (habitat) and actor-specific environment, the outside world. It is evident that bodies, artefacts, and environments shape creative processes (Malinin, 2019). First, it involves an experimental examination of embodied metaphors associated with creative thinking reified through mood-setting in the 4M framework. Second, it involves a systemic approach that implicates the whole creative process of problem finding and forming, generating, testing, and elaborating on ideas to develop a product or service (Malinin, 2019). This approach in the 4M framework is reified in the Movement-methods and through Movement-concepts. Thus, Modifiers are available for tweaking both the Mood-setting and the Movement-methods and the Movement-concepts.

We recognise that testing and evaluation of the 4M framework and its grounding in the 4E radical embodied cognitive science still will have to be established to document the actual value of the framework.

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The Effectiveness of Playful Augmented Reality Media for Teaching Early-Primary Students

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Abstract: Hybrid learning has become the only solution to ensure the learning process still occurs in place of traditional classroom activities during the Covid-19 pandemic. Following this condition, the phenomenon of "Zoom Fatigue" has emerged. Some of the symptoms reported are decreased learning motivation, low attention, and reduced responses. Thus, a refresher process, including the use of new playful and frugal learning media is necessary for varying children's learning activities. A learning intervention was designed to teach anatomy playfully as part of a biology curriculum. The Augmented Reality technology used in this research is a Humanoid 4D+ mobile application with flashcards, developed by Octagon Studio. This media displays information virtually on a smartphone screen when the application uses the camera to scan flashcards containing visual markers. A hybrid learning space is formed as students can see information virtually. But, physically, they are in control because they run applications and choose the type of flashcard they want to scan. The research was undertaken in several learning parks in Solo City, Central Java Province, Indonesia, with a total of 43 volunteer teachers and 132 early primary students participating. Previously, the ACES team (part of a UKRI funded project) had provided online training on the use of this media with teachers. Each teacher would then implement the media for all students in each learning park. The teachers demonstrate the media and each student takes turns running the application to view information virtually, therefore experiencing interactive learning. The qualitative approach was conducted for capturing teachers' perceptions of Augmented Reality media. A survey using the JISC online platform was distributed to capture participants' reflections on the activities and media used. Based on findings, the media appears beneficial, effective, and efficient for teaching anatomy concepts. Its virtual features can attract the children's attention and teachers do not need to bring a lot of physical teaching aids, just one application to explain all organ system concepts. Students can learn playfully on their own and feel new learning experiences. The results indicated that the intervention could create playful and frugal activities which build student engagement as a potential solution to address issues of Zoom Fatigue. The next stage of the project will involve volunteer teachers implementing the technology more widely in their classes.

Keywords: ACES, Playful, Frugal, Zoom Fatigue, Augmented Reality, Early-Primary Students

1. Background

The arrival of Covid-19 in Indonesia marked the sudden and simultaneous occurrence of the highest peak in the implementation of online learning in all schools in Indonesia. The learning process is carried out remotely, communication is carried out using video conferences, and the presentation of learning materials and evaluation of learning is carried out online with a home-based activity format. Video conferencing as a communication medium has subtly led to *Zoom Fatigue* due to the long duration of time allocated for video conferences (Fauville, 2021; Salim & Tandy, 2022). *Zoom fatigue* is a condition that describes the fatigue associated with the excessive use of virtual communication platforms (Wolf, 2020). *Zoom fatigue* symptoms are marked by forgetfulness and difficulty concentrating, frustration and irritability with co-workers, and physical symptoms like muscle tension, pain, fatigue, and insomnia (White, 2021). During observations by Peper, Wilson, & Martin (2021), approximately 80% of 350 participants indicated it was harder to focus their attention and stay present while taking online classes. There is more isolation, anxiety, and depression compared to face-to-face classes, although much of this may be due to COVID-19 social isolation. Students often appear unresponsive when attending synchronously online, which negatively impacts student-instructor interactions and nonverbal dynamics. Therefore, it is necessary to modify media, design, and learning methods with various applications that do not require high concentration so that fatigue during online learning does not occur (Pustikasari &

Fitriyanti, 2021). There are still few studies that publish the creativity and innovation of educators to modify learning into playful online learning to make it more fun for students. Meanwhile, an understanding of fun learning design is an indispensable element in maintaining the motivation and quality of children's learning. According to Broadhead, P. (2010), high-quality play experiences are essential for good early years education. Rice (2009) presented findings that playful learning can effectively motivate and improve student engagement, promote creative thinking towards learning, and develop approaches toward multidisciplinary learning. The authors propose to optimize the fun online learning process for students by modifying the learning design using an Augmented Reality media mobile application, equipped with flashcards, by adapting the principles, aspects, and indicators of playful learning (Arnab, Morini, and Clarke, 2018) and frugal education (Masters, 2021).

2. Literature Review

2.1 2.1 Augmented Reality Humanoid 4D+ Mobile Apps

Augmented Reality (AR) is a technology that enables virtual content to be seamlessly merged with the real world. Historically, the earliest AR systems discovered in the early 1990s were developed at the U.S. Air Force's Armstrong Laboratory (Rosenberg, 1992). AR experiences have become widely available on mobile and handheld devices in the last few years due to the emergence of smartphones that combine fast CPUs with displays, cameras, graphics acceleration, compass, GPS sensors, and even gyroscopes (Azuma, 2011). For educational purposes, Augmented Reality (AR) information content can be accessed by scanning or viewing images through applications on mobile devices. Displays can be videos, images, 3D animations, games, QR codes, or whatever you want (Brown, 2015). Korenova's research results (2019) confirmed that using visualization with Augmented Reality results in a deeper understanding, greater motivation, and strongly supported student creativity. The new method motivated students, those students cooperated very well, and learning was constructive.

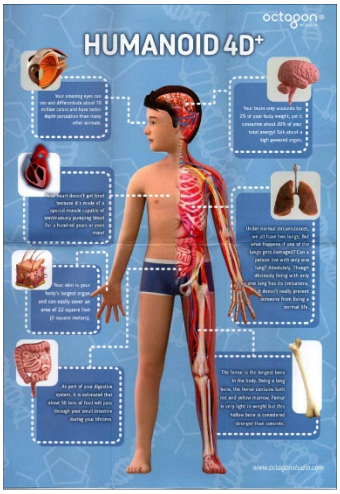


Figure 1: Screenshot of Humanoid 4D+ Interface.

The Humanoid 4D+ application developed by Octagon Studio is a mobile AR app designed to teach anatomy. This application is equipped with a physical card containing visual markers linked to information on various body organ systems. The app presents 3D visualizations of organ systems inside the human body, allowing users to explore human body parts in detail. Users can experience the anatomy exploration in Augmented Reality using the markers provided (App screenshot with AR label). When pointing the app at the markers, users can start exploring parts of the Skeletal System, Muscular System, Respiratory System, Digestive System, and Skin. The Humanoid 4D+ application was chosen in this study to measure its effectiveness for teachers in teaching early-primary students.



Figure 2: Humanoid 4D+ Interface application in use with students

(Participants were given consent forms and agreed to photographs being taken of them participating in activities with Humanoid 4D+)

As shown in Figure 2, Humanoid 4D+ can be played by children anywhere at any time. In addition, the principles of creativity and innovation are clearly used by educators to modify learning into a playful experience, making it more fun and engaging for students. An understanding of fun learning design is an indispensable element in maintaining motivation and quality within the children's learning.

2.2 ACES Project Research

This research is part of the ACES project, funded by the UKRI. ACES (A Community-Centred Educational Model for Developing Social Resilience) is investigating and seeking transformative educational models for young people toward a more inclusive, safe, and resilient society. One of the ACES principles is using Playful Learning and Frugal Education during the intervention for children in Indonesia.

2.2.1 Playful Learning Principles

Play is one of the most critical ways young children gain essential knowledge and skills (UNICEF, 2018). For this reason, play opportunities and environments that promote play, exploration, and hands-on learning are at the core of effective pre-primary programmes. According to Roberts, Arth, and Bush (1959), play is a model or theatrical simulation, such as a game. Games provide the necessary skills that may be needed later in life. Even the simplest games contain a complex set of properties. Children usually understand the basic concepts of a game depending on their development level. Higgins (2000) also proposed that the nature of play involves a trial and error process to overcome the challenges and obstacles it poses, thus promoting the development of logical thinking and problem-solving skills (Higgins, 2000). Similarly, Lieberman (1965) found that using play in learning can favor the cultivation of divergent thinking. Students discover the importance of elements such as empathy, purpose, meaning, art, creativity, and teamwork in their learning regardless of the specific disciplines they are pursuing (Arnab, Morini, and Clarke, 2018).

Playful learning is an educational approach in which a state of being is facilitated that is creative, explorative, experimental, active, and immersive. It stimulates intrinsic motivations and the flow state of the learner. The learning activities are focused on constructing knowledge or skills in a fun and experimental manner. Playful learning aims to stimulate the construction of new knowledge and skills by letting students wonder, experiment, fail, take a risk, construct, and reflect critically on the content and their learning experience (Witton,Toft-Nielson, Norgard, 2017). The focus is more on dynamics, the spontaneous, creative experience, and less on game mechanics. Playful learning can be found in humor in the classroom, roaming around in a virtual environment, or weekly reflection challenges. Playful learning has six overarching categories: Autonomy, Fun, Agency, Curiosity, Iteration, and Social (Arnab et al., 2020). The following will explain each aspect of the Playful Learning principles that is predicted to be found in the Augmented Reality media used in this study.

Table 1: Playful Learning Aspects and Indicators (Arnab et al., 2020)

Autonomy	**Fun**	**Agency**	**Curiosity**	**Iteration**	**Social**
Sense of Control	Easy	Capability	Perceptual	Repetition	Associative
Freedom of expression	Hard	Responsibility	Empathic	Experimentation	Competitive
Meaning	People	Accountability	Epistemic	Reflection	Collaborative

The Autonomy aspect suggests that learning designs created should be able to train children to make decisions and participate without pressure (sense of control), facilitate them to express feelings (freedom of expression), and help children find meaning in their activities (meaning). The Fun aspect recommends that interventions should be able to make children feel happy, curious, feel adventurous and fantasize (easy-fun), finish the challenge based on their abilities (hard-fun), and collaborate with others (relationship). The Agency aspect will be met if children can develop their capability through the activity (capability), can respond actively and encourage their commitment (responsibility), and can give the ownership of their performance (accountability). The Curiosity aspect will be shown if learning design can provide sensory stimulations, children start to explore, ask questions, and take risks (perceptual), become aware and understand other people (emphatic), and motivate children's desire for knowledge (epistemic). The Iteration aspect reflects activities for different skills when completing a task multiple times (repetition), exploring different ways to solve a problem by testing their strategy, finding alternatives (experimentation), and helping track the way they address/solve a problem (reflection). The Social aspect is the last part of the playful learning principles. The learning design indicated that children start to learn from other people by asking questions, talking, negotiating about the activities at hand, connecting actions and choices (associative), developing and discovering shared goals (collaborative), and comparing their progress with others (competitive).

2.2.2 Frugal Education Principles

The concept of Frugal Education is described as "harnessing the power of design thinking, leveraging available resources, and embracing sustainability to develop creative, practical, and sustainable education for all." (Masters, 2021). Over the course of the ACES project, further research into frugal education has been undertaken to refine the guiding principles and to develop a set of nine associated aspects for consideration when designing and adapting educational practice (Arnab, Mahon, Masters, et al., 2021). These aspects were informed by (1) the development of a 'learning, playful, and frugal mapping framework' for developing 21st century competencies and resilience, and (2) the design of playful and frugal interventions in collaboration with ACES partners for delivery within case studies across Malaysia, Vietnam, and Indonesia.

Table 2: Frugal Education Principles and Aspects (Masters, 2021)

Design with an Open Mind	**Leverage Available Resources**	**Build at the Speed of Need**
Creativity	Resourcefulness	Minimalism
Collaboration	Practicality	Sustainability
Openness	Resilience	Iteration

When applying frugal education practices for designing hybrid learning through interventions using Augmented Reality media, we need to consider the frugal education principles, and their respective aspects, and how they might be applied to the intervention to deliver frugal and sustainable learning designs toward varying early-primary learning activities and addressing *Zoom Fatigue*. First, learning intervention should be designed with an open mind which can be achieved by fulfilling the respective aspects. As an example, the activity should be more creative by combining ideas and creating innovative ways to foster experimentation (creativity), it should include the role of children to participate (collaboration) and be accessible by allowing others to apply, adapt, and build through clear and detailed guidance (openness). Second, the learning intervention should be able to inspire children through the use of available materials in the local environment and wider community that can be recycled to create new resources and materials (resourcefulness). The design needs to be practical and flexible

to engage more participants, especially those living in rural areas where the use of technology is limited (practicality) and it needs the flexibility to adapt gracefully to unforeseen circumstances (resilience). Lastly, the learning intervention design should be made more economical by reducing administrative processes and minimizing resource costs (minimalism), considering the environmental impact of the design on the wider community (sustainability), and creating simple designs and iterating on them through a continuous cycle of improvement and refinement (iteration), enabling educators to more effectively design, resource, build, and deliver quality education with limited resources.

2.3 Early Primary Students of Solo Mengajar

This project focused on the role of community stakeholders and young people in understanding, engaging and integrating playful approaches into informal education spaces in Indonesia. In this study, we collaborated with the Solo Mengajar NGO community. “Solo” is the name of the city the NGO community originates from, and “Mengajar” is the term to explain a learning mentoring activity carried out by volunteers to children in the area. Solo Mengajar NGO is a moral movement community in education for young volunteers in Solo City, Central Java Province, Indonesia, established independently on May 25, 2012, and is not affiliated with any political party or organization in Indonesia. Solo Mengajar uses a social assistance strategy through socialization, mediation, and facilitation in increasing citizens' awareness of the fulfillment of children's education rights (Pamungkas, 2018). One flagship program is Playful Activities, which participates in learning activities and play in several villages and nine learning parks. The main activity of Solo Mengajar is to strengthen the understanding of basic concepts within subject matter, instill, and teach a good attitude while helping children develop their interests and talents. The local community mentions the presence of Solo Mengajar as a Free Private Learning Service for their children who have learning difficulties (Susanti, A., 2021). We involved 43 volunteer teachers and 132 assisted students from the NGO Solo Mengajar for participation in this study. Currently, most children come from rural areas.

3. Method

A qualitative approach using the Participatory Action Research (PAR) method was conducted for this research. PAR is a research activity carried out in a participatory manner among citizens in a community or broader social sphere to encourage transformative actions (changes in better living conditions). Thus, according to the term, PAR has three main pillars: the research methodology, the action dimension, and the participation dimension. This means that PAR is carried out by referring to specific research methodologies, it must aim to encourage transformative action, and must involve as many citizens or community members as possible as PAR implementers themselves.

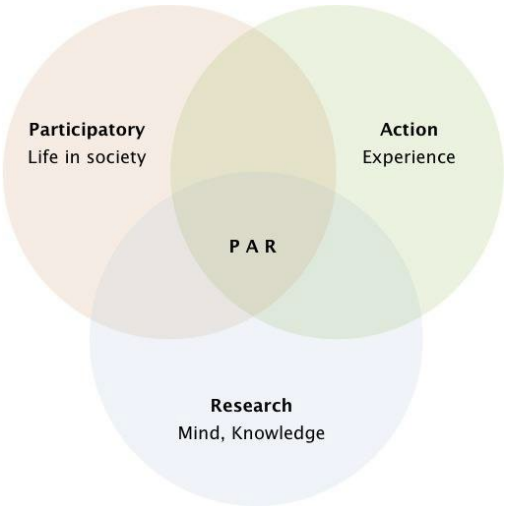


Figure 3: Participatory Action Research Diagram (Chevalier, J.M. and Buckles, D.J., 2013)

PAR offers an opportunity to deconstruct and reconstruct professional knowledge in the light of participants’ stances and theories in use, including their experiential and practical knowledge. It can support a group of practitioners to: consider a particular aspect of practice and its effectiveness collectively; examine how it is informed by knowledge and best practice (e.g. research, theory, policy, and practical knowledge); and explore where improvement may be required and implemented. As a collaborative research methodology, it offers significant benefits because it can contribute to the discovery and development of conditions and actions required for sustainable change. PAR aims to increase participant awareness of external forces affecting

decisions in their lives, including promoting self-confidence and the capacity to develop decisions that enable a new level of awareness and competence. PAR's effectiveness in enhancing the understanding of the inter-relationship between personal agency, professional competence, and knowledge translation has been examined with the use of case study material from a professional development research project (Wimpenny, K., 2010).

3.1 Plan: Planning Online Training for Participants

After analyzing the community's goals, needs, and initial conditions through a series of meetings, a plan was made to provide training on the use of various types of playful learning media to teach the community using the Gamification Webinar series format. The webinar materials presented many kinds of child-friendly playful learning media including the Augmented Reality Humanoid 4D+ media. 43 Solo Mengajar teachers were appointed as participants of this study. Due to restrictions on offline activities during the Covid-19 pandemic, 'Training of Teachers' was presented online in the format of the ACES Gamification Webinar Series.

3.2 Action: Distributing Learning Media to Participants

After finishing 'Training of Teachers', we distributed 20 flashcard packages and serial numbers for the Humanoid 4D+ mobile application. One serial number can be used to activate the Humanoid 4D+ application on three different smartphones. One flashcard package consists of 10 cards containing different information about all human body organ systems. Technically, the teacher alternated the use of applications and flashcards between 132 early primary students. Each teacher then implemented the media for all students in each learning park. The teacher demonstrated the media and each student took their turn running the application to view the information virtually and therefore experiencing interactive learning. This was achieved by pointing the app at markers on the flashcards to virtually explore the human organ systems.

3.3 Observe: Conducting an Online Survey To Measure The Effectiveness of Learning Media

When the implementation process was completed, the next step was to input the questionnaire in the form of open essay questions into the JISC Online Survey tool. The tool is designed to support Academic Research, Education, and Public Sector organisations in carrying out data collection and is accessible at https://www.onlinesurveys.ac.uk. The JISC Online Survey was used to collect, process, and display data for this research. Once the research instrument was prepared, a link to the questionnaire was shared directly with the participants. The use of questionnaires aimed to determine the effectiveness of media in explaining the human organ system concept to early primary students. The teacher guided the children in answering the reflection questions given while accompanying the children during the media implementation process and then uploading data as documentary evidence of their participation into the cloud storage system. From this data, participant statements regarding the use of media can be analyzed based on their responses in each question then the advantages and barriers could be identified in order to produce a recommendation. Data was collected from 19 March 2021 to 21 April 2021.

3.4 Reflect: Analyzing Data and Findings

After collection, the data were analyzed thematically.

4. Results Section

The paper is organized to respond to the problem of Zoom Fatigue faced by children. The study found that the Humanoid 4D+ application used in learning intervention provides new learning experiences. The app is very beneficial, effective, and efficient for building early-primary student engagement and increasing children's responses to teacher instruction, so is therefore a good potential playful solution for preventing *Zoom Fatigue* symptoms during the learning process due to the excessive use of virtual communication platforms (Wolf, 2020).

4.1 New Learning Experiences

When participants were asked about what they gained from this intervention. Each gave a positive response. Participant 1 noted, "I learned about the human body using a new method in the learning process." Participant 2 commented, "I got new lessons and experiences regarding the use of human organ recognition applications." Participant 3 said, "It turns out that learning the basic concepts of biology regarding anatomy can actually be done through advanced 4D technology," and some of them mentioned in similar statements that they felt very enthusiastic, were not sleepy anymore, felt interested, and quickly understood the concepts being taught during the learning process.

This suggests that the app may have a positive impact on student engagement as the children start to engage in a new learning experience through virtual interactivity. This finding follows Azuma's opinion (2011) that Mobile

Augmented Reality is one of the fastest-growing research areas partially due to the emergence of smartphones that provide powerful and ubiquitous platforms.

4.2 Usefulness

When they were asked about the benefits of the Humanoid 4D+ application in supporting the learning process, all participants gave the same answer, stating that the application was beneficial.
A majority of participants agreed that the app was useful. One participant noted that the app *"was very useful",* another stated it was "*extremely useful and easy to use*", and others stated that the app was useful to be used in the learning process.
Participant 2 commented, *"Learning human organs no longer needs to use physical teaching aids".*
Others mentioned that it was v*ery u*seful because it could attract attention. One participant went on to explain that teaching *"through gadgets which are of course more interesting".*

The ease of this app to use and to attract children's learning attention can be a solution to prevent and to reduce difficulty concentrating, frustration, and fatigue in children during the learning process as the symptoms of Zoom Fatigue mentioned by White (2021).

4.3 Effectiveness and Efficiency

When they were asked about the effectiveness and efficiency of the app in the learning process, the majority of participants answered that it was very effective and efficient. Some participants answered for various reasons.

> *The majority of them said that the app can be used anytime and anywhere without the need to bring physical props. Two participants commented that this Humanoid 4D+ app is effective for children. Others said that the app is very effective because it is playable, has much knowledge and is suitable for facilitating learning while playing. Two more participants noted that the app is effective and efficient, can save time, cost, and is easy to understand.*

These statements indicate that the app is effective because of its practicality and suitability for teaching the concepts to early-primary students whenever and wherever it is required. It is efficient in terms of time, money, and effort. The app does not necessitate complicated devices, nor does it necessitate prolonged periods of intense study, as is the case with online learning. Learning apps can be accessed repeatedly without worrying about missing the teacher's ongoing lesson or online presentation. As a result, it may be a viable option for reducing learning fatigue in children, both mentally and physically, and keeping children away from long periods of video conferencing attendance that could potentially cause *Zoom Fatigue* (Salim & Tandy, 2022).

The next stage of the project will involve more teachers implementing the technology more widely in their classes. Some participants complained of poor responsiveness when their smartphone internal memory was full, which could prove to be a potential limiting factor for the app's use. Providing an adequate number of smartphones to facilitate a larger number of students could make the learning activity more time-efficient, however, it would also increase the overall resource cost. If the school cannot provide enough smartphones for all students, an alternative solution would be to utilise an LCD projector to display the app contents on a whiteboard and the children could freely choose the type of flashcards they want to virtualize in turn. Also, the strength and the availability of internet access provided can be a limiting factor as AR technology requires internet connectivity to visualize objects on markers. Thus, the internet signal strength can significantly affect the application's performance. It is recommended to provide training, not only for volunteers but also for students, before starting learning experiences due to some children not having experience with using applications and therefore needing volunteer guidance in order to participate.

5. Conclusions

In conclusion, the use of playful augmented reality media is very beneficial, effective, and efficient at preventing *Zoom Fatigue*, and has been especially effective during the pandemic for teaching anatomy concepts to early-primary students. The study used a qualitative approach involving the thematic analysis of data collected through an online survey. The app can reduce the *Zoom Fatigue* symptoms as students are engaged and interested in a new learning experience. Students are actively involved in using this application accompanied by interesting flashcards so they can scan and get the information. In the learning process, students carry out image identification activities that require them to move, use physical objects, and communicate with their friends, further limiting the potential for *Zoom Fatigue*.

The playful and frugal aspects helped to identify and inform how the learning design and learning environment can be made. Several playful learning aspects were identified in AR Humanoid 4D+ app, such as: easy-fun, experimentation, perception and capability due to the apps ability to build involvement and interaction between children; through raising children's curiosity to discover more and become fully immersed in the activity context, and enable the sense of adventure, fantasy and make-believe; providing sensory stimulations (touch, auditory, and visual) to inspire and stimulate children's imagination and/or discovery; facilitating children in mastering new digital and contextual literacy skills.

We also found that these interventions align well with the frugal principles. When using Humanoid 4D+ app, teachers can create learning designs that foster creative thinking and problem solving by proposing tasks to identify potential causes of several diseases in the human body. In addition, collaboration involving participation among students is necessary to collectively identify parts of the body by working together and sharing ideas. Through this activity, teachers can listen to the participants, encourage participation, understand student needs, and identify areas of improvement. Teachers can recycle available materials such as used cardboard and paper to print new flashcards for use with the AR mobile apps. Through this practice, teachers and participants motivate one another to be resourceful by creating something new using what is available in the local environment. The design needs to be practical and flexible to engage more participants, especially those living in rural areas where the use of technology is limited. Teachers can create simple designs to be easier to create and manage. For as little as £2.76 in English pounds, or around IDR 50,000, parents or teachers in rural locations can purchase one Humanoid 4D+ application with flashcards that can be used simultaneously on three different smartphones to facilitate virtual learning. The cost is significantly lower than purchasing a single physical organ educational toy, which is five times more expensive (£13.66 or IDR 252,000), therefore making the app a more viable alternative, provided there are sufficient smartphones available to use the software, which in this case there are. Children can access the application for free at several learning parks managed by Solo Mengajar. This provides educators in rural locations with the ability to deliver engaging education practice with minimal resource cost, whilst also limiting online interactions as a way to mitigate against the potential for *Zoom Fatigue*.

5.1 Limitations

The authors wish to acknowledge that the participation in this study was limited to only several learning parks with a small number of participants. Further research would significantly increase the number of sample distributions through which to measure the effectiveness of the intervention.

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Visualization, Serious Games and Decision Making

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Abstract: One of the most important objectives of serious games is to detonate behavioral changes of participants. Serious games generate engagement, they are meaningful, entertaining, and immersive. However, when the game represents a complex system, it contains a great number of variables and the relationship between its decision components are not entirely clear. Consequently, it is necessary to offer a set of tools that increase the data visualization of the players and help in the decision-making process must be provided. In our university, logistics professors have designed a simulator for logistics decision making. On the one hand, the game has gained acceptance from the student community, but on the other hand, several students do not accomplish a satisfactory performance. Therefore, these students fail to notice lots of variable interrelationships in the game, and they do not develop the skill required to follow a good decision-making process. The goal is two folded. On the one hand, the improvement of the participant's comprehension of a complex logistical system must be reached. On the other hand, the clarity on the decision-making process has to be laid out. A set of visualization support tools were created to accomplish those objectives. Neither of the tools aim to influence the decision-making process nor to show decision alternatives to the participant, but to highlight a few key performance indicators, constraints, and data that the students can use when making the decisions. In this paper it is presented how the participants have improved their understanding about the logistic system represented in the game, when the support tools are used. Moreover, their motivation has increased, they are more involved and committed to learn. Overall, their decision-making strategies have been modified and they have shown a better comprehension of the game structure. This paper contributes to underline the importance of visualization in student's learning, considering that currently big data, industry 4.0, as well as internet of things have gained a significant relevance in our everyday life. The design of strategic games involving these new variables are necessary. The more complex a system, the greater the number of visualization tools to strengthen the comprehension of the system are required.

Keywords: Higher Education, Educational Innovation, Visualization, Serious Games, Logistics Education

1. Introduction

The decision-making process frequently occurs in our modern life. Decision making is one of the key processes within the business environment and in all organizations. Decision consequences have a direct impact on the structure and in the profit of a company. Competitors and the demands of the market lead to continuous company innovation. Strategic decisions must always be made to improve their reputation. Besides being effective and agile, decisions must comply with the least margin of error, since a bad decision made at the wrong time with lack of context analysis can have irreversible consequences for the company.

Many studies have been carried out on the decision-making processes as well as on the different resources that are used for improvement. Data visualization and data plotting are useful tools in decision making, since they summarize large data sets. Moreover, they show trends, outliers, patterns, and clusters, among others.

This article presents a Logistic Simulator (LOST), which is a game that simulates a company where the participants make a significant number of logistical decisions. This game has been used in several courses and important results in the acquisition of knowledge, motivation, and the development of various skills such as self-study (Pacheco 2022) have been obtained. A data visualization and an analysis tool have been developed to improve the decision-making of the students who participated in this game. The influence of data visualization on LOST player's decision making is also included in this article.

2. Review of Literature

In recent years, the use of serious games has increased. In serious games, the main objective goes beyond fun or entertainment, they have a training purpose that leads to the acquisition of skills. These types of games have been used in a wide range of sectors such as the military sector, the health industry, the educational system and the corporate environment, among others. Serious games for educational purposes have a positive impact as it

provides an effective strategy to engage students in learning activities and stimulate cognitive processes such as information recognition, deductive/inductive reasoning, and problem-solving skills (Minović et al, 2015; Pacheco 2022; Almeida 2019).

Serious games may be of interest in the development of 21st century skills such as reaction speed, multiple attention spans, relational aptitude, high achievement motivation, greater tolerance to frustration, ability to take risks, to solve problems and to make decisions (Romero & Gebera 2012). (Almeida 2019) proposes the use of a serious games to assess and to develop emotional intelligence skills.

To name some authors such as (Laamarti et al, 2014; Vlachopoulos & Makri 2017; Zhonggen 2019; Roedavan et al, 2021) who present reviews on serious games in areas such as education, well-being, advertising, cultural heritage, interpersonal communication, and health care. (Pacheco 2022) introduces a serious game to teach logistical concepts. This author presents evidence that the game has an important influence on the motivation of students, on the development of student commitment, and on their self-directed learning. (Sierra 2020) states that a student-learning performance expectancy is essential to accept serious games.

Serious games can be used not only to teach, but also to measure knowledge acquisition after playing, presenting an empirical study based on data science (Fernández et al, 2020).

In general, serious games not only provide an interesting amount of data to the player in order to select strategies and to make decisions, but also to the teachers or to the managers so that they can monitor and evaluate the player's performance or learning. The way in which the data is presented to the player or the teacher, enters the field of visualization. (Minović et al, 2015) present a visualization tool, associated with a game, that allows them to monitor student learning in real time allowing them to react and to influence the general learning process.

Visualizations incorporate design options for data access, data transformation, visual representation, and interaction. To interpret a static display, a person must identify the correspondences between the visual representation and the underlying data (Cottan et al, 2012). Researchers have tested taxonomies of information visualization techniques (Cavaller 2021; Ruys 2020; Cottan et al, 2012; Daassi et al, 2005) so that implementers can quickly identify various techniques that can be applied to their domain of interest.

In the process of searching, interpreting, and comparing data, data visualization plays a crucial role. The increased use of computational tools in the teaching-learning processes and the rise of big data have made data analysis an essential component of educational technology. In the context of serious games, the development and the integration of learning analytics has not yet reached its full potential. (Vidakis et al, 2019) presents a library that seeks to capture and simplify data in the context of a serious games. Data visualization can be used transversally as a tool in both data formalization and data analysis processes, being one of the most powerful mechanisms for autonomously exploiting and analyzing the implicit meaning in the data. The pros of visualization are the sharing of knowledge by externalizing internal understanding, the improvement of the thinking ability and the formulation of new ideas. Visualization can also give a better understanding of relationships (Li et al, 2016). (Lowe & Matthee 2020) have performed a systematic review of the literature, identifying the requirements of visualization tools, classifying them into six groups: dimensionality reduction, data reduction, scalability and readability, interactivity, rapid retrieval of results, and user assistance.

In contemporary society, decision makers are daily faced with complex problems. People can make quick and accurate decisions if they have access to all the relevant information. Various information systems can help decision makers in such an effort presenting an adequate and understandable visualization approach in an appropriate way (Burnay et al, 2019; Po et al, 2020). Similarly, (Park et al, 2021) have analyzed 16 studies in which they found that visualization seems to bring advantages by increasing the amount of information delivered reducing the cognitive and the intellectual burden to interpret the information for decision making. Data visualization can also be misleading. If the correct data is not properly presented, nonexistent conclusions can be superficially drawn. Therefore, data visualization should primarily be about presenting good data in an unbiased way (Benoit 2019; Park et al, 2021).

3. Logistic Simulator – Data Hound and Visualizations

LOST is a business game with an emphasis on making decisions about the logistic operation of a company. The game is immersed in a platform aimed to the teaching of logistics called the "GOAL Project." When students enter the platform and the game, they see a series of videos that explain the game's operation, the logic, and the purpose. Upon entering LOST, they receive a set of randomly generated data with the same degree of difficulty as of their classmates. There are five scenarios on the platform, each with an increasing degree of difficulty. Each scenario also involves a higher number of decisions that the players must make.

Students can play the game as many times as possible, but there are regular deadlines to reach specific pre-established goals. These dates regularly depend on the policies of each course. Within the game, several indicators are visible to students. However, teachers have observed that if the students do not have enough knowledge, they may have difficulties interpreting the indicators or establishing strategies to correct the system's performance. In addition to this series of indicators (which are also visible to teachers), each of the player's decisions is stored in a database that the teacher can review, if necessary, to suggest various strategies to the students that might let them have better game results. In the first version of the game, there were some videos with suggestions so that the students who were playing it could obtain good results.

Students make empirical decisions on the number of the produced items based on the data obtained in each simulator turn. Some of the included tasks are the counting of required raw materials, the analysis of the quality of the materials, the choice of the supplier and how to transport the items to the store. The student's challenge is to maximize the profits on each turn. This task is the result of the analysis of the supply versus the demand, the costs of the raw materials and the transportation, which can face unforeseen scenarios in the game.

The game also contains a "leaderboard" in which students compare their performance with other class or team members. When the objectives of a scenario are achieved it is possible for students to access a new scenario that will contain new variables or more complex situations in which they must make even more decisions. Table 1 shows a short description of the different scenarios. All scenarios contain problems related to logistics issues, and all of them include elements of forecasting, inventory, transportation, production management, and supplier selection. However, the complexity of the situations and the objectives to be achieved become increasingly difficult. Undisplayed data is presented in .xls or .csv files. which cannot be analyzed immediately and clearly.

Table 1: Characteristics of the game scenarios.

Characteristics	Game Scenarios				
	1	2	3	4	5
Number of factories	1	1	1	1	2
Number of stores	1	1	3	3	5
Volume Discounts	×	✓	✓	✓	✓
Large transportation vehicles	✓	✓	✓	✓	✓
Small transportation vehicles	×	✓	✓	✓	✓
Single transportation route	✓	✓	×	×	×
Multiple transportation routes	×	×	✓	✓	✓
Defective production	×	✓	✓	✓	✓
Possibility to acquire new machinery	×	×	✓	✓	✓
Overtime	×	✓	✓	✓	✓
Variable prices of raw materials	×	×	×	×	✓
Machine breakdowns	×	×	×	×	✓
Change of price of finished products	×	×	×	×	✓
Contracts with customers	×	×	×	×	✓

The application is named Data Hound and Visualizations (DHV) is designed in the R programming language in its 4.1.2 "Bird Hippie" version (R Core Team, 2021). It runs and it is launched through a graphical interface through shiny packages (Chang et al, 2021) and a shiny dashboard (Chang & Borges 2021). The application runs from its own server and can be accessed from any web browser.

3.1 Structure of the Data Hound and Visualizations

The structure of the application is a variation of the methodological proposal of the seven steps for decision making by Flores, Molina, Alvarez (2020). The Data Hound and Visualizations (DHV) menu was designed focused on the 4 final steps of this methodology. The user can freely navigate through each stage, but a completion of each section in order to obtain the desired results is required. In Figure 1 the three sections of the menu and some subsections are shown.

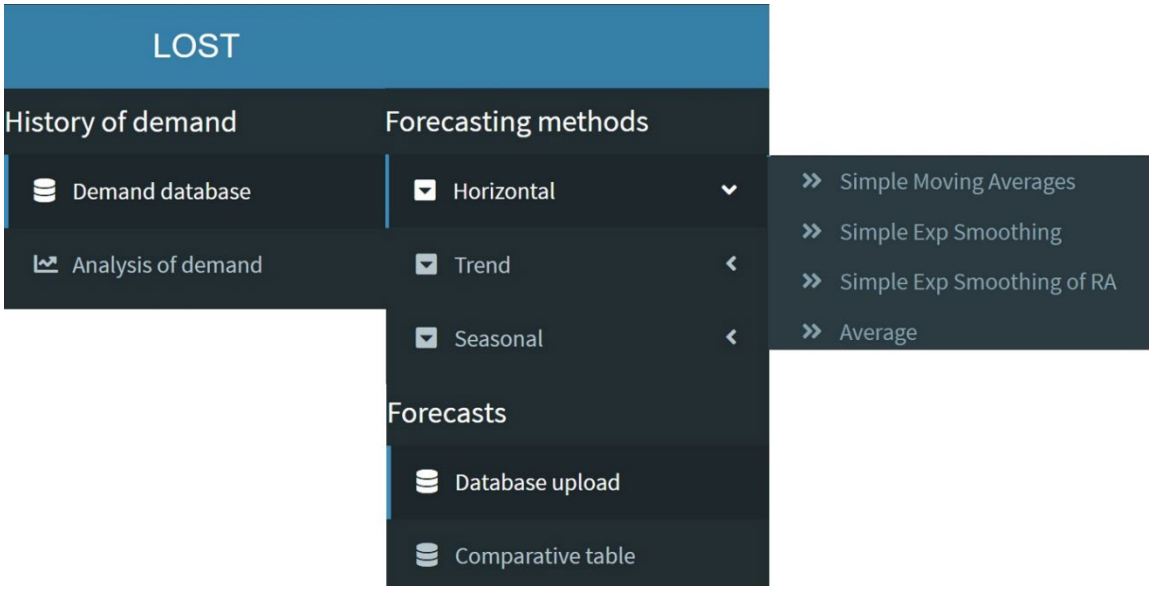


Figure 1: Data hound and visualizations (DHV) main menu.

In the History of demand stage two sections are found. In the first section, data obtained from LOST is loaded, in second section, a first interactive graphical analysis is carried out. A summary is given for each of the game products. Given the structure in which DHV was programmed, it is easily adaptable to any number of products (variables) and records (observations). For the purposes of this work, it was adjusted to 8 products (variables) and to 104 weeks (observations). The second part of the menu consists of the Forecasting Methods, we will analyze 3 types of methods, each of which is made up of various methods so that the user can select the one that best fits the data. There are 9 methods available, each with its inputs, outputs and interactive graphs.

The Forecasts section is described in detail in section 3.3. Visualizations, scatter plots for time series and pivot tables were used for product analysis. An interactive dashboard, composed of inputs, calculated values according to user data and donut graphs, was used for the decision-making of the number of produced items.

3.2 System Client – Server

The application is made up of a client-server structure, which takes as input the data obtained from LOST. Once a level is completed, the output is shaped by a series of resources that will be used as guides for decision making. Users can download their respective game data to be uploaded to DHV.

Users access DHV through a web browser. Given the purpose of this tool, it works in parallel with LOST. All the data required for the DHV is obtained from LOST. As stated in the menu description of the application, the first step is to upload the Demand file. In Figure 2 the processing diagram of the DHV system is shown.

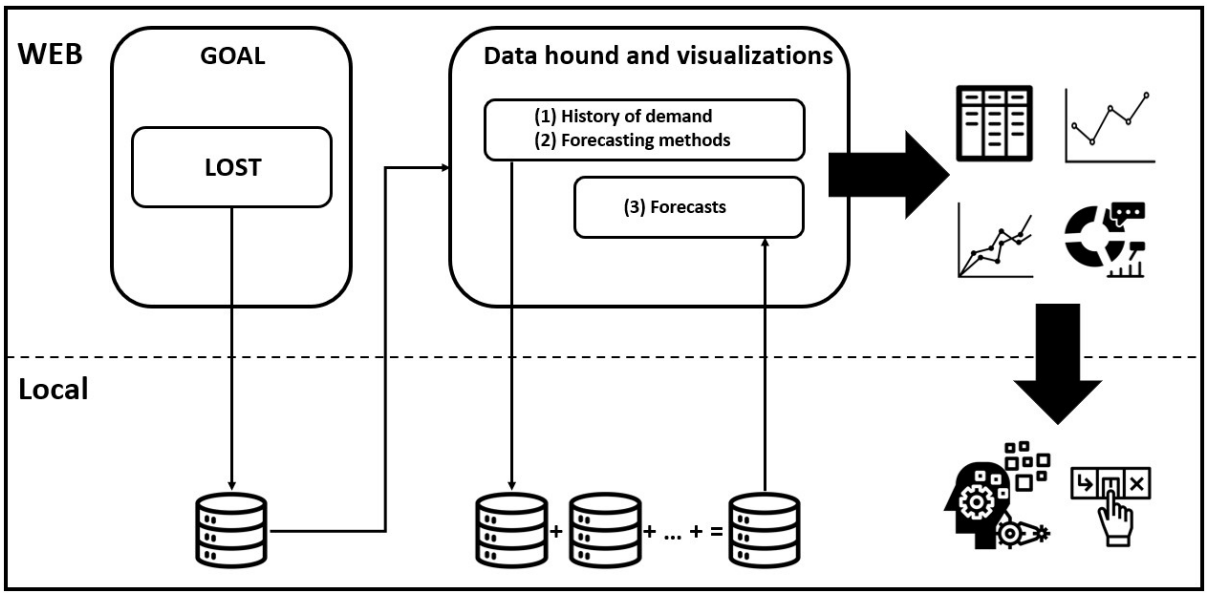


Figure 2: Data Hound and Visualization operation diagram.

3.3 Visualizations

The use of visualizations is a crucial part of DHV. Visualizations are a support to the decision-making process; they are not intended to decisively influence the final decision of the users. The tables, the graphs and the indicators were selected to highlight the key aspects when playing LOST.

Figure 3 shows the structure of the nine forecasting methods, which contain a comparative graph between demand data and forecast data according to the selected method (left top). In the lower left part, the graph of the probability of satisfying the demand in the following period is shown. The product selector and the input parameters of the selected method are presented in the upper right part, as well as the corresponding input for the method to be used. Descriptive statistics and precision measures appear in the table to the right, as well as downloadable data for the selected method.

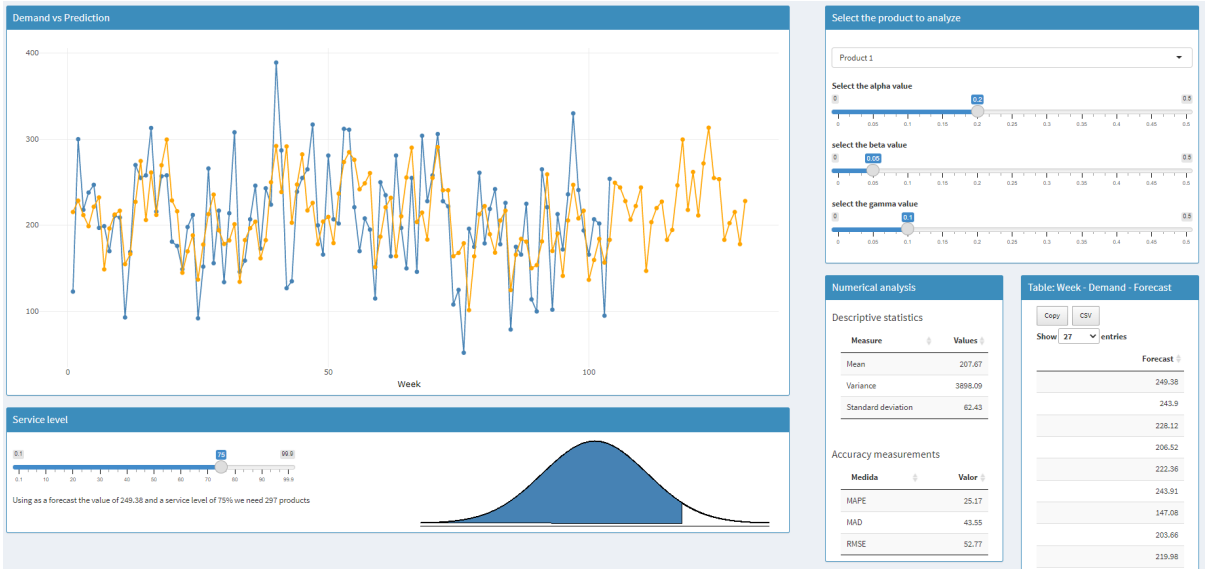


Figure 3: Structure of forecasting methods.

The last section of DHV can be seen in Figure 4, which works with two data sets, is presented. The first data set is obtained from the forecasting methods selected by the user. The second set of data comes from Lost and corresponds to the database of companies and suppliers.

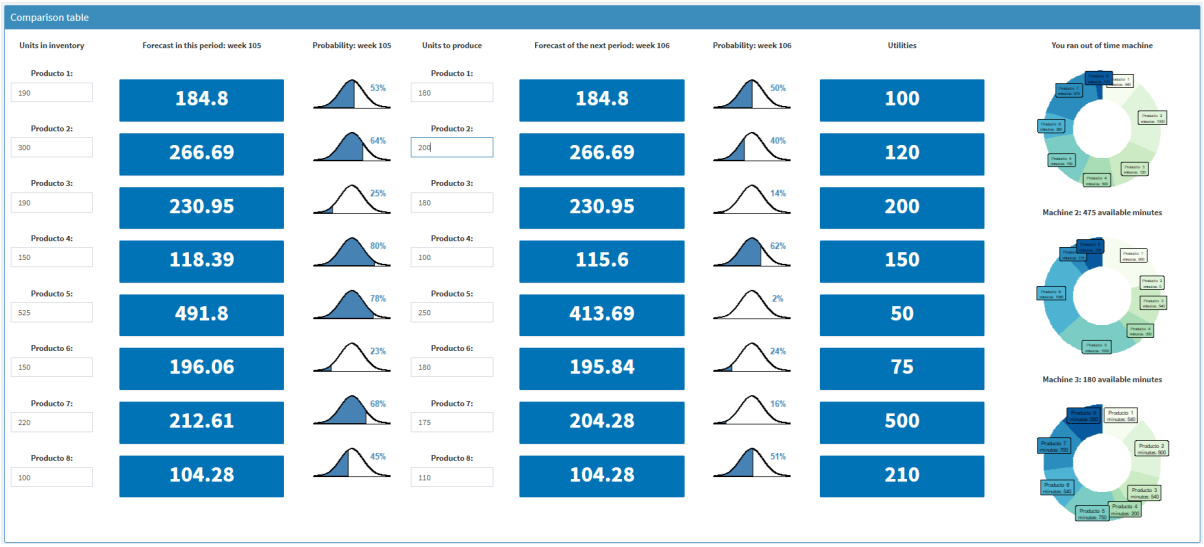


Figure 4: Dashboard of final stage for decision making.

In this board the quantities of each product can be changed in real time, these values are used to calculate the predictions and the probabilities of satisfying the demand of the next period of the game. The donut graphs give information on the available machine time, and it has a minute counter. This board presents a summary of the variables of greatest interest so that the user can decide which product to select and the number of items to produce. Easy-to-interpret visualizations were chosen in pleasing-to-the-eye formats. Complex visualizations were not used since the data needed be presented in the simplest possible way. Traditional graphs and mixtures of them were taken into account, with components of colors and shapes that enhance the understanding of the data visualization.

4. Methodology and Data Analysis

The experiment can be unfolded in two stages. In the first stage, the LOST simulator and the first version of the DHV are used. As a result of this first stage, adjustments and improvements were made to DHV. This first stage is qualitative research that intends to observe how the students used the DHV to make logistical decisions if the information and the graphics that the app provided were sufficient and presented in a proper way. Finally, it was intended to find the shortcomings of the app as a visual support for LOST. In this stage, interviews and perception surveys were carried out on students.

The second stage has a quantitative approach. LOST and the latest version of DHV are used. Variables related to the functionality, the processing and the interface of the tool are measured, as well as the decision-making of the students. Each stage is detailed below.

The first stage was used as a pilot, which helped defining the key parameters and the way in which various visualizations were going to be presented.

It is important to mention that our university carries out the implementation of a new academic plan that prevented the authors of this paper from having several groups of the same subject. Moreover, the length of the class was limited. Therefore, future work will include an out and an intra group design. The students of the first stage were registered in different periods, and in different subjects but with topics related to the game.

In order to avoid learning bias, one of the goals is to verify that students improved their results by using the tool and not by continuous use of the simulator.

4.1 First stage – i-Week

The first stage of our experiment was depleted within the framework of the 2021 i-Week. The i-Week is an academic activity that is carried out nationally at Tecnológico de Monterrey. For an entire week the students carried out various activities such as seminars with experts from the industry, theoretical classes, practical workshops, among other activities. A group of 33 students had a one-week immersion to play LOST and to solve well-defined logistical challenges using DHV to support their decision making. During this period, a perception

survey was applied to the 33 students, who came from 5 campuses: Mexico City, Monterrey, Puebla, Querétaro and Toluca. The students were from different engineering fields from the last three semesters of their career. Random interviews were also conducted.

The survey had 9 items in the Likert scale ranging from 1 = Totally agree up to 7 = Totally disagree. The first two questions were related to the help provided by the visualization tools. The third and fourth questions referred to the opinion of the students about graphic resources. The fifth question dealt with the usability of the visualization tools. The sixth and seventh questions asked whether visualization tools helped them solve complex problems or not. The last two questions were related to the visualization support in decision making.

The Likert scale was especially useful in this experiment since a quantification of the student´s opinion was required. In this sense, the response categories capture the intensity of the respondent's feelings towards a statement. There are studies that conclude that, from 8 levels, the results obtained are the same as with 9, so adding levels will not result in a greater variation in the results. Consequently, the optimum number of items lays within 7 or 8 levels (Joshi et al, 2015).

The survey was applied twice. The first time at the beginning of the week, after playing LOST. The second time was applied after showing them the visualization application DHV to be used when playing LOST again. Before starting the last game, they were taught how to use DHV. All the students attended a lecture on visualization and decision making.

4.2 Second stage

The second stage of the experiment was carried out in two groups of the Operation-Management subject aimed at fourth-semester-Industrial-Engineering students. The sample included 17 men and 19 women, that is 36 students in total.

The LOST game was introduced to the students, and they were asked to play the entire first level of the game. The students got the gist of the tool functionality by making logistical decisions, and by solving problems.

Once the first level was fully completed, a 15-item Pre-test was applied. It had three sections: Tool functionality (seven items), Data processing (two items) and User Interface (six items). The responses were presented on a Likert scale that ranged from 1 = Totally disagree up to 10 = Totally agree.

Subsequently, the students participated in a forecasting workshop for decision making and were introduced to the DHV app (version 2.0). Students learnt how to use DHV to analyze data for trends, seasonality, etc. They used DHV to make forecasts. Once this part was done, the students were ready to play LOST again. Depending on the decisions of the students, the game generated new routes, therefore, it was not the same game that they played before the Pre-test, but it had the same characteristics. At the end of the game, the Post-test was applied. The results are presented in the next section.

4.3 Data Analysis

4.3.1 Stage one survey results

To analyze the results of the seven-level-Likert-scale survey, new variables were created to represent each topic of interest. Concepts learning Q1+Q2, Graphic resources Q3+Q4, Usability of the tool Q5, Support offered to solve complex problems Q6+Q7 and Help in making decisions Q8+Q9. Table 2 shows descriptive statistics for these variables.

Likert scale data can be analyzed as interval data, i.e. the mean is the best measure of the central tendency. Here the average is used to calculate the functionality, the processing, and the interface gain.

On the other hand, after taking advantage of the Likert scale so that the student can differentiate the degree of agreement with the statement, a breakdown of the data into three intervals was used, through the mean and the deviation, imitating the analysis of data with normal distribution.

Table 2: Descriptive statistics of the new variables.

Variable	N	Minimum	Maximun	Mean	Std. Deviation
Concepts LOST Q1+Q2	33	2.00	14.00	5.5758	4.02360
Concepts DHV Q1+Q2	33	2.00	13.00	5.0909	3.80266
GraphResources LOST Q3+Q4	33	2.00	12.00	5.7879	2.83678
GraphResources DHV Q3+Q4	33	2.00	14.00	5.4242	3.78344
Usability LOST Q5	33	1.00	7.00	4.0909	1.75648
Usability DHV Q5	33	1.00	7.00	2.7273	1.87538
CoplexTask DHV Q6+Q7	33	2.00	14.00	5.3030	3.79543
CoplexTask DHV Q6+Q7	33	2.00	14.00	6.6061	3.41814
DesicionMaker LOST Q8+Q9	33	2.00	14.00	6.3333	3.67140
DesicionMaker DHV Q8+Q9	33	2.00	14.00	5.5152	3.80067

To facilitate the study, the bins using the cutoff points obtained are found as follows: $\mu \pm 0.75\sigma$

where μ is the mean and σ represents the standard deviation of the variable. The student percentage whose opinion falls into the three ranges was taken into account as:

$$[minimum, \mu - 0.75\sigma), [\mu - 0.75\sigma + 0.75\sigma], (\mu + 0.75\sigma, maximun]$$

Table 3 shows the percentage of students in each range on the topics impacted by the LOST and the DHV tools. It was found that 69.7% of the students perceived that LOST helped them to learn the concepts, while 36.4% of the students perceived that DHV as an additional aid to learning the concepts. These percentages increased when considering the intermediate ones, this is: 78% and 76% respectively. 42.4% of the students thought that the graphic resources presented by the two tools were good. If we add the intermediate ones, it would be 81% in both tools. 36.4% of the sample said that LOST was easy to use, while 30.3% consider that the tool helps in solving the tasks carried out.

Table 3: Percentage of students in each range on the topics impacted by the LOST and DHV tools.

		LOST			DHV		
Questions	Topics	High	Intermediate	Weak	High	Intermediate	Week
Q1-Q2	Learning Concepts	69.7%	9.1%	21.2%	36.4%	39.4%	24.2%
Q3-Q4	Graph Resources	42.4%	39.4%	18.2%	42.4%	39.4%	18.2%
Q5	Usability	36.4%	36.4%	27.3%	30.3%	48.5%	21.2%
Q6-Q7	Solve Task	30.3%	45.5%	24.2%	30.3%	51.5%	18.2%
Q8-Q9	Decision Maker	42.4%	36.4%	21.2%	36.4%	45.5%	18.2%

4.3.2 Stage two: survey results

The 15-item questionnaire was studied through three variables: tool functionality (Functionality), data processing (Processing) and user interface (Interface). They were obtained with the average of the corresponding questions and continuous values between 1 and 10 were obtained.

Seven questions are related to the functionality of the tool, these questions deal with the visualization and its relationship with decision making. A high score on "Functionality" indicates that the student believes that the way the tool displays the resources such as the tables, the data, and the graphs facilitates the decision making. Two questions are related to data processing. A high score in "Processing" indicates that the student considers that the tool has what it takes to be able to manipulate, to process and to represent the results. Six questions relate to the user interface. A high score on "Interface" indicates that the student is comfortable with colours, the way the information is presented, and the visualization layout.

Table 4: Statistics on Functionality, Processing and Interface.

Variable	Funcionality Pre	Funcionality Post	Processing Pre	Processing Post	Interface Pre	Interface Post
Mean	9.004	9.405	6.708	8.167	8.222	9.009
StDev	0.838	0.662	1.857	1.608	0.987	0.921

To proceed with the data analysis, the following variables (Hake 1998; Loza et al, 2022) were used. Average pre-test grade:

$$\langle Pre \rangle = \frac{1}{N}\sum_{i=1}^{N}(Pre_i)$$

where (Pre_i) is the pre-test grade of the student *i*; and the average post-test grade:

$$\langle Post \rangle = \frac{1}{N}\sum_{i=1}^{N}(Post_i)$$

where $(Post_i)$ is the post-test grade of the student *i*. $N = 33$ is the sample size.

Student Functionality/ Processing /Interface gain:

$$G_i = \langle Post_i \rangle - \langle Pre_i \rangle$$

Group Functionality/Processing/Interface gain:

$$G = \langle Post \rangle - \langle Pre \rangle$$

Student relative Functionality/Processing /Interface gain:

$$g_i = \frac{Post_i - Pre_i}{10 - Pre_i}$$

The relative Functionality/Processing /Interface gain for a given student is a measure of the actual gain that the students achieved, i.e., $Post_i - Pre_i$ with respect to the maximum gain that they could have obtained $10 - Pre_i$. The group relative Functionality/Processing /Interface gain has a similar meaning but refers to the whole group:

$$g = \frac{\langle Post \rangle - \langle Pre \rangle}{10 - \langle Pre \rangle} = \frac{G}{10 - \langle Pre \rangle}$$

Table 5: Gain in Functionality, Processing, and Interface.

	Pre	Post	G = Post - Pre	g = G / 10 - Pre
Tool functionality	9.00	9.40	0.40	0.40
Data processing	6.71	8.17	1.46	0.44
User interface	8.22	9.01	0.79	0.44

Table 5 shows a gain in functionality of 40% and 44% in processing and interface. This means that by playing LOST with the support of DHV, students perceive that there is an improvement in visualization, which leads to better data analysis and decision making in a comfortable design environment.

Figure 5 shows the graph of functionality, processing, and interface, where is observed that the results post-test are significantly higher than the pre-test.

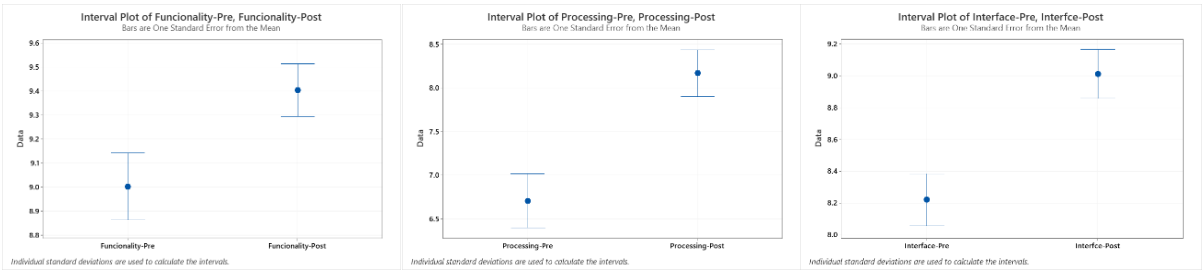


Figure 5: Interval plot for Functionality, Processing, and Interface.

5. Conclusions

The app Data Hound and Visualizations (DHV) is designed to guide users in their decision-making process. To perform this task, the tool focuses on three key aspects: functionality, processing, and interface. The obtained results indicate that LOST and DHV help the users to better understand the problem, to analyze it and to solve it. Large amounts of data complicate the decision making, so the use of a tool capable of processing large data sets, presenting the data sets as tables, graphs and interactive dashboards, besides performing calculations in

real time, relieves the user of various complex tasks. With the help of DHV, the user can focus on the understanding and on the analysis of the scenarios proposed in the LOST game. DHV is scalable to new and diverse versions of the game, it is even possible to adapt it for environments other than LOST.

This paper contributes to underline the importance of visualization in student learning, considering that currently big data, industry 4.0, internet of things have gained relevance in our modern world. Not only is it necessary the design of strategic games involving these new variables, but it is imperative to keep in mind that the more complex a system, the greater the number of visualization tools required to strengthen the comprehension of the system and the student learning.

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Climate4Kids: A Gamified App Teaching about Climate Change

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Abstract: As per Deterding et al. (2011), gamification can be defined as using game design elements in non-game contexts and it is used to increase motivation and engagement. That is why there are already gamified application to change people's behavior when it comes to environmental protection. Climate change is a complex topic which is for younger children aged 6 to 10 years quite often too abstract to understand properly. Therefore, a browser-based app is being developed that aims at teaching basics about renewable energy, mobility, greenhouse effect, soil sealing, heat insulation and the like. Using elements of gamification like points, collecting stars, planting trees digitally, a changing background (depending on the progress made) as well as a narration about the protagonist Mani (a groundhog that is affected by climate change) and his friends encourage the children to use the app not only at school but also at home. By telling stories which introduce the topic, the children get a first understanding of how everybody of us affects the environment and what we can do to prevent effects of climate change. Moreover, instructions for easy hands-on experiments are used to make children experience certain effects and/or consequences of climate change. The app seeks to meet children's emotional needs acknowledging feelings, emphasizing solutions, and encouraging action. The contribution shows how elements of gamification are included in the app to ensure that children are motivated to engage with the topics as well as stay immersed and transfer the learnings into their every-day-life.

Keywords: Digital game-based learning, climate change, gamification, primary school

1. Introduction

Using games for education has got quite a long tradition, dating back to Plato, for example, when he claimed that children needed to play the same games again and again to make sure that society remained stable (D'Angour 2003). Moreover, he stated that children's play was essential for their learning and especially for developing their character (Bergen 2014). In the 16th century, Comenius wrote a paper dealing with the didactic use of games for children. He claimed that playing – apart from the importance of acting out different situations - was an important activity for relaxing and blowing off steam. Especially progressive educational movements at the end of the 19th and beginning of the 20th century like Froebel, Pestalozzi and Montessori stressed playful activities as significant to children's learning (Bergen 2014). Of course, all these people did not talk and write about digital games but about board games, free play and drama. However, they all recognized the significance of playing as learning process. In the 21st century the method of digital game-based learning became more common at schools. Gee (2005) suggested that videogames of good quality also offered quality learning experience. Another approach having become more widespread is gamification. As per Deterding et al. (2011), gamification can be defined as using game design elements in non-game contexts. Gamification is used to increase motivation and engagement (Cheong, Filippou & Cheong 2014). Burke (2014) defines gamification as using game mechanics as well as experience design to digitally engage and motivate people to reach their goals. Although the roots of gamification can be traced back to marketing (Bogost 2014) and the concept has faced substantial criticism, education and training has introduced gamification and gamified elements as well. As Ramirez & Squire (2014) point out, gamification should not be seen as inherently good or bad. There are many techniques that might be used in various contexts to make learning more challenging, motivating or fun, but some are more frequently used over others. As a review of empirical literature by Majuri, Koivisto & Hamari (2018) has shown the top five elements studies had a closer look at are points, leaderboards, badges, challenges, and levels whereas the psychological outcomes studied mostly concentrate on perceptions of use, perceived enjoyment, engagement, motivation and perceived usefulness.

When it comes to using gamification to tackle the effects of climate change, Douglas & Brauer (2021) showed that there already some games and gamified apps around that promote sustainable behaviour. The reason therefore is that gamification "has the potential to engage individuals and various stakeholders towards climate change through interactive, participatory and meaning-making communication" (Rajanen & Rajanen 2019, p. 254). In a systematic review, Galeote et al. (2021) found out that game-based interventions engaging players with climate change issues and research about it have been growing over the last years.

2. Teaching climate change to primary school pupils

In primary school, subject teaching is responsible for preparing primary school pupils for participation in and shaping an increasingly complex and technological world. Lessons should be designed by teachers in a way that supports learners to explore their immediate and indirect environment in a constructive process, to actively acquire world knowledge and to argue and reflect on their decisions (Greiner et al. 2019). Knowledge and skills should not only be learned and understood by the learners in the individual context, but also classified in contexts and made available under different requirements. Understanding the complex factors that are responsible for climate change is not easy, even for adults. However, understanding how climate change works, what is it caused by, which effects there are on the planet and mankind as well as countermeasures and social options for countering climate change is one of the central issues of our time. This importance is also reflected by including the topic *Climate Action* within the Sustainable Development Goals by the United Nations. The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people can enjoy peace and prosperity (https://sdgs.un.org/goals).

A research project at the University College of Teacher Education Carinthia dealt with the question of how to teach the complex causes and consequences of climate change in primary school. In order to be able to understand the very complex relationships and linking in this context and therefore be able to act in a climate-friendly manner, a step-by-step, relatable knowledge needs to be acquired. This is best done by experience-based development and collection of conceptual knowledge modules for both teachers and students. The focus is on cumulative knowledge building as well as understanding-oriented and concept-related learning. Children are not a blank slate but start every topic with ideas in their heads that are fed by everyday experience. New ideas are thus always formed through the transformation and expansion of these existing ideas. The theoretical background of this question is the theory of conceptual change. Conceptual Change Theory (Vosniadou 2008) understands learning as a constructive and meaningful process that always builds on prior knowledge. According to this theory, new information is placed in relation to existing knowledge, classified and, in the case of incompatibility, is either discarded or initiating a process of reorganizing the existing knowledge. As a rule, this means that the existing knowledge is only changed to the extent that the new information can be integrated into the existing model. Thus, the focus has to be on the question to what extent learning products can influence the development of understanding and the development of key professional insights among learners. Freytag et al. (2021) developed a teaching-learning model to serve teachers as a basis for planning their lessons. As a first step in the above-mentioned project, the participating teachers attended a series of three workshops. In the first workshop, the teachers were presented with a teaching-learning model suitable for competence-oriented teaching. The teachers worked out key professional insights into climate change and made connections to central concepts. In another workshop, the educators dealt with the integration of hands-on experiments in the classroom. The topics of storytelling and gamification were dealt with in a final workshop. The teachers then planned their own competence-oriented lessons using the planning scheme described in the teaching-learning model. For this purpose, the topic of climate change was limited to three essential technical concepts: The concept of conservation: "Nothing is lost in the world", the concept of energy: "You can do a lot with energy" and the concept of interaction: "Factors influencing each other" (Wodzinski 2015). Based on these concepts, the lessons were then implemented in three primary schools. The learning products created during the project implementation formed the basis for the reflective examination of key professional insights and central concepts. They are regarded as the starting point for a cumulative development of understanding of a content or object. In the teaching-learning model, learning products are not understood as final products of learning, but as a central element of the learning and understanding development process. These products make learning progress and gaps in understanding visible and provide starting points for designing lessons (Leisen 2016).

Discussing and reflecting the learning products together with teachers and other learners helps the learners to link the processed content with professional insights and key concepts. The project results have shown that teachers do not see learning products as final products of learning, but as a central element of the learning and understanding development process. The results obtained show that the causes and consequences of climate change should already be dealt with at school with 6- to 10-years old pupils and therefore this project served as the basis for the conception of the Climate4Kids app.

3. Climate4Kids – a gamified app

Climate change can be seen as the primary threat for our planet (Poushter & Huang 2019). As understanding climate change and counter measures is one of the main issues of our time and needs to be dealt with also at primary school, a multilingual app called *Climate4Kids* was developed to give primary school pupils between the ages of 6 and 10 a better understanding of the subject of climate change. With *Climate4Kids* an age-appropriate introduction to a complex topic that will accompany primary school students throughout their lives will be provided. In order to design the app towards the needs of the target group and to depict the content and graphics as authentically as possible, children and pre-service teachers were involved in a co-constructive development process throughout the development period. The app is based on three pillars: First, picture stories are presented which were written and drawn by pre-service teachers and primary school pupils. These picture stories give a narrational frame to draw users in and to arouse interest in the topic. Using the storytelling method, picture stories were written on relevant topics of climate change. Storytelling is a narrative method that is used to pass on explicit, but above all implicit knowledge in the form of symbols, metaphors, or other means of rhetoric. It is mainly used in digital media, but has a long tradition (Landrum, Brakke & McCarthy, 2019). The audience does not only consume the story by listening, reading, or watching, but can also be actively involved as a prosumer in the implementation. The method is based on the following: A vividly told story attracts the attention and focus of other people more easily than a logical, factual presentation of facts. That is why storytelling has been used for thousands of years to pass on complex knowledge in cultures (Yilmaz & Cigerci, 2019). The story can be based on facts, be fictional, or combine both, fact, and fictional elements. Storytelling generates memories and promotes learning. Kearney (1994) claims that especially difficult topics like climate change can better communicated when wrapped into a story. Secondly, the app provides instructions for simple hands-on experiments, that every child can do at home without requiring any special equipment. The third aspect is a more playful. Pre-service teachers have come up with (non-digital) card and cardboard games about climate change and tested them with pupils. Products of all these three parts - digital picture stories, hands-on experiments, and child-friendly games - were then integrated into the app.

The following sections will describe some of the features of the application in more detail as well as connecting them to the concepts of gamification.

3.1 Background story

The app as a new learning and teaching tool is browser-based and will be available in four languages (German, English, Italian and Slovenian). Based on the knowledge how important storytelling is – especially for children – *Climate4Kids* does not only use storytelling for the picture stories but also for linking the different parts of the app (picture stories, hands-on-experiments, and games). The children are guided through the app by marmot "Mani" (cf. figure 1). Marmots are also severely affected by climate change because their habitat becomes increasingly warmer. Due to the rising temperatures, the marmots often feel too hot for looking for food during the day, which means that they cannot store enough fat reserves for the winter and consequently have to starve. Due to this fact, the marmot was considered an ideal avatar to guide children through the app. Mani is the first non-playable character the children come across – he helps with login to the app, guides through experiments (cf. 3.3) or gives a brief overview what the picture stories (cf. 3.2) are about. The character also slightly changes depending on the section of the app – for example: For the story-section he is depicted reading a book and for the experiment section he is wearing a white laboratory coat. Like in many children stories, Mani acts like a human, explaining, showing emotions, or doing different activities. Users of the app should link the character Mani with *Climate4Kids* at once and children should relate to the marmot.



Figure 1: Mani reading a story

3.2 Picture Stories

Picture stories serve as an introduction to a topic and are intended to spark the pupils' interest in the topic and motivate them to engage and interact. Pupils and/or pre-service teachers wrote picture stories dealing with the following topics (content): mobility, renewable energies, waste, albedo-effect and soil sealing. The pictures and the text were made into a film using professional speakers to tell the stories in different languages. These stories take children in fairy-tale like worlds where animals can speak and act like humans (for example a dog going on skiing holidays) or depict more realistic situations like the story Daisy`s journey around the world in which a girl asks a mother what happens to her rubber duck Daisy after she has been disposed. All the stories aim at teaching a lesson about global warming – such making use of the didactic method of telling stories which became popular in the middle of the 18th century when folk stories were emerging as a genre of children's literature (Lewin, 2020). Most of the stories told in the app have a character who acts in an improper way (out of not knowing better) and is taught how to take countermeasures to global warming. In order to haver longer lasting learning effects, the pupils are asked to answer some questions after having listened to the story. These quizzes consist of single or multiple-choice questions reflecting the lessons learned from the story. Although there are more questions for each picture story (about five for each), there is one central concept the pupils should learn. Therefore, the app already matches the requirements of the new curriculum for primary school (to be introduced in September 2023) which put a focus on competences instead of learning facts by heart.



Figure 2: Pupils with their hand-made drawings

3.3 Hands-on experiments

Working on the topics requires a multidisciplinary approach; understanding climate change requires scientific knowledge, but also practical knowledge, as well as sociological and economic knowledge. It is therefore of great importance that pupils experience haptic elements for lasting understanding. This is ensured by offering instructions for hands-on experiments within the app. The decision against a computer-generated simulation was made because as Hufer (2017) puts it learning sometimes needs to be non-digital. Hands-on experiments are primarily intended to increase the motivation of the pupils to deal with the topic of climate. The experiments should be simple, astonish the pupils, but also make them question processes and events and therefore stimulate discussions. Using *Climate4Kids*, the teacher now has the opportunity to have pupils rediscover apparently quite simple effects or to try to simplify relationships that seem to be quite complex. By working on the experiments on their own, the pupil can proceed in an action-oriented manner and make his own experiences (learning by doing). This ensures sustainable education. The simplicity of most experiments allows a wide variety of variations of how to implement them.



Figure 3: Mani carries out the finger warmer experiment according to the instructions on the right

The hands-on experiments, which require little material, nearly no preparation and can be done quickly, should pupils engage and make them curious about and interested in the topics. The experiments are easy to understand and can be used in classroom teaching as a supplement, introduction, or summary of the topic. What is more, the experiments should draw pupils' interest to research, as the hands-on experiments can also be tried out alone at home.

3.4 Games

Pre-service teacher students at the University of Klagenfurt have designed non-digital games for the target group that are intended to successfully connect the digital with the analogue. A deck of cards on the subject of soil sealing, for example, can be printed out and played using the app. Because only by playfully dealing with a topic can the full potential of the children be tapped (Hüther & Quarch 2016).

3.5 Gamification Elements

In order to connect all the above-mentioned parts of *Climate4Kids* and to make sure players can really engage with the app in a playful way, some more elements of gamification have been introduced. In 3.1, we have already discussed the use of a background story to immerse the target group more in the environment of the app. As the objective of the app is that children have a look at all the parts (especially listen to / read the picture stories, do the quizzes afterwards and do the hands-on-experiments), a reward system was integrated: When the quiz questions have been answered correctly, players can earn trees which will be planted at the start screen of the app (this screen is also used to choose the topic the learners want to deal with and are the direct way of choosing a picture story). Figure 4 shows what the start screen looks like when players have planted two trees (which means they have answered two questions correctly) and what it looks like when 21 trees have already been

planted (meaning in summary 21 questions have been answered correctly). Therefore, advancement in the game can be seen at a quick glance at the start screen.

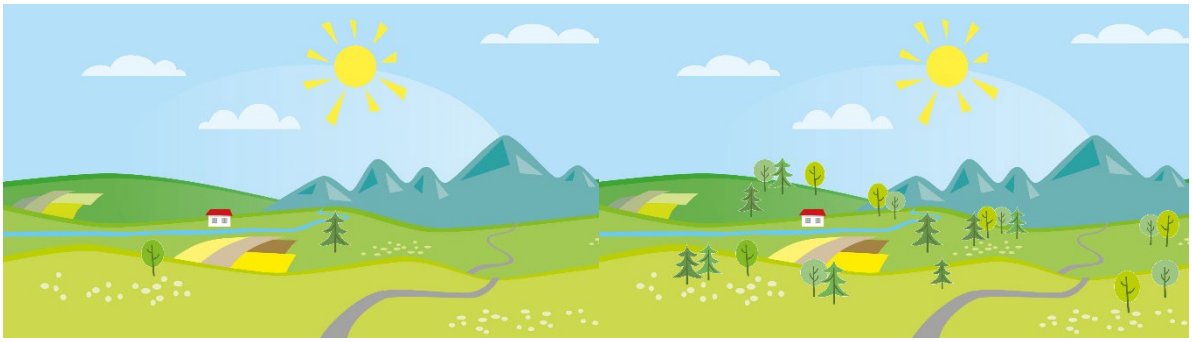


Figure 4: The more activities the player completes, the more trees will be planted

Instead of a traditional progress bar, the app uses the face of the planet getting happier and happier depending on how many trees have already been planted. This way, planting of the trees shall also be associated with the healthiness of our planet by the players. The face of the planet will change throughout the game. Additionally, there will also be a health bar showing players how many trees they need to plant to reach the next level (or face) of the planet.



Figure 5: The more trees are planted, the happier the planet will get

Visualizing the progress in the way shown should fulfil different purposes: First of all, pupils should be encouraged to answer the questions in the quizzes correctly to be able to plant more trees and try quizzes more often until they get all the answers correctly. To encourage redoing the quizzes, the full number of points (and trees) can only be reached when all the questions have been answered correctly three times. This way, the number of repetitions is raised which also makes lasting learning effects more probable. If a question is answered incorrectly, pupils will not be presented with the correct answer but will be referred back to the picture story (or the experiment). Second, pupils can only collect all the trees if they not only listen to / read the picture stories but also do the hands-on experiments as quiz questions will address both areas. This way, the rewards should help to tackle all the areas of the app and not only concentrate on one or two topics or not doing the hands-on experiments at all. However, the app will only present questions to picture stories / experiments that have at least been opened once by the player. Third, various player types according to Bartle (1996) shall be addressed: Achievers want to collect all the trees as fast as possible and reach the last level – the healthy earth face. Explorers will love the back story and the picture stories as well as Mani as the character guiding them through. As the app does not provide a multiplayer mode, those players belonging to the group of Socializers need to be catered for outside the game by talking about it in classroom and exchanging game experiences. The last type, Killers, could have easily been targeted by integrating a high score board. However, as the topic of the application does not agree with competition, this element was not used.

4. Conclusion and outlook

The app *Climate4Kids* aims at showing primary school children which effects of climate change there are and – even more important – what everybody can do to take countermeasures. By tackling the complex topics in a playful way, the project team hopes to give teachers a tool which can be used versatile. However, the intention is that the children and young people do not only use the app in classroom settings, but also at home. This way, parents can also get informed about the topic of climate change and can talk with their children about the themes depicted in the app and find solutions on an individual level how to take small steps to improve life for nature and mankind. Since the content is developed in a playful way and users can make their own haptic experiences through the hands-on experiments, a lasting effect is guaranteed. In order to find out if the app

really works in primary school contexts, playtesting and evaluation of the app is planned for the fall of 2022 when pupils of some chosen schools will be introduced to the app and use it in classroom teaching. As not only children but also primary school teachers belong to the target groups, both groups will be asked about their experiences using qualitative and quantitative approaches. The results of this evaluation will be used for adapting and improving *Climate4Kids*.

The elements discussed in this paper were developed in a first step. In follow-up projects, the use of the Climate4Kids app will be expanded and more topics and elements will be integrated to make playing and learning experience even better. Modern methods of digitization, such as gamification, digital picture stories, storytelling, games and freehand experiments are to be expanded with other didactic methods. The application in its current form introduces primary school children between the ages of 6 and 10 to the topic of environmental protection and climate change. In a next development step, the Climate4Kids app is to be further developed so that it can also be used by children between the ages of 10 and 14. In terms of content, it is planned that the concept of the circular economy, such as the sustainable consumption of electrical appliances, will be incorporated into the app. The general goal of this follow-up project is to bring the issues of climate change, environmental protection, and the circular economy more into the focus of the younger generation, to work out the need for ethical action through an understanding of the scientific background and to motivate players to take specific steps. Sustainability is particularly evident in the use of the project results, which are not only available free of charge to a small group of people involved in the project, but to all pupils who want to use this app. The app as a new learning and teaching tool will be used internationally and will be available in five languages (German, English, Spanish, Italian and Slovenian). To ensure that the new versions of the Climate4Kids application developed in this project will be used in classroom teaching of primary schools, further training courses for teachers (train the trainer) on the topics dealt within the application, such as the sustainable use of electronic devices, will be developed at the University of Teacher Education in Carinthia. These training courses can then be offered regionally, nationally and internationally for teachers.

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Nursing XR: A VR Application to Teach Decision Making to Student Nurses

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Abstract: This paper validates an approach to the design and development of VR applications that are integrated into the curricula and address fundamental student needs. To accomplish this, a case study describing the process undertaken to create Nursing XR, a wound dressing scenario where the patient is discharged home and requires follow up care and treatment by a nurse. The aim of the VR application is to support nursing students in developing their communication, risk assessment, holistic assessment, and person-centred clinical decision-making skills. To design Nursing XR, needs and initial requirements were collected via a workshop with student nurses. The workshop, which involved 10 student nurses and two lecturers in nursing from two Universities (Co-Is) and was led by the PI, supported by the learning technologist and the head developer of the company used for development of the software. Results from the workshop identified two major needs for the students: the need to undertake practical applications of the procedures learned in the lectures and the need to build confidence in the skills required of a nursing student. These needs were the foundations for the design process, which followed an artefact-based approach. The artefacts generated during the design were also used to elicit additional interaction and software requirements from the nursing lecturers. An iterative lean development process was followed by the company for the software implementation. Throughout the development, students and lecturers were involved as user testes ensuring that the user experience of the application was satisfactory, and the application fit for purpose. In this paper, we describe the high-level design and development process followed by the multidisciplinary team to develop Nursing XR and report initial qualitative findings from the workshop focus group.

Keywords: Extended Realities, Virtual Reality, Design Process, Nursing, Education

1. Introduction

Recent developments in extended realities (XR) technologies have brought new ways to envision teaching and learning within the classroom, opening the door to experiential learning (Kolb, 2015) by digitally recreating situations that are close to reality and allow students to make informed choices and practice what they have learnt.

Nursing is a subject that requires students to be able to develop emotional connections and holistic assessment skills (NMC, 2018). These characteristics lend themselves to exploit the ability of XR technologies to create experiential learning opportunities for students within a safe simulated environment (Saab et al., 2021).

The use of XR technologies as a tool to teach procedural, emergency, soft, and psychomotor skills in nursing subjects is not novel (Plotzky et al., 2021). For instance, Oliveira et. al. (2021) developed a serious game tool aimed at developing emotional competencies for nursing students, Elliman et al. (2016) recreated a hospital ward with dementia patients, whilst Choi (2019) developed a simulation to teach wound care procedures.

However, processes and practices for the development of XR applications for education that are integral to the curriculum rather than isolated interventions are still lacking (Hamilton et al., 2021, Gilardi et al. 2021).

This paper contributes to the subject of serious games by presenting Nursing XR, a VR application focused on a wound dressing scenario for injured patients recently discharged into their home from hospital. The application focuses on facilitating simulated practice and developing students risk assessment and decision-making skills. The paper also contributes to the subject of XR applications design for education by providing a case study of the application of Gilardi et al.'s (2021) design process.

2. Related Work

The application of XR technologies to nursing education is a subject that is emerging in the academic literature. Recent literature reviews (Plotzky et al., 2021, Saab et al., 2021, Chen et al, 2020, and Fealy et al., 2019) highlight that the subject still needs further development and the need of rigorous studies and a unified language to describe XR technologies in the field. They also indicate that VR has the potential to facilitate engaging forms of learning, which is supported by Saab et al.'s (2021a) and Baxter and Hainey's (2020) studies on student views on the use of VR for education; and offer a cognitive walkthrough for procedures (Choi, 2019). There is a lack of studies that discuss the effectiveness of the use of VR in nursing education. Chen et al.'s (2020) meta-analysis highlights that VR is effective in improving knowledge, but it is not more effective than traditional methods in skills, satisfaction, confidence, and performance time. This partially aligns with Smith and Hamilton's (2015) study which found no significant difference between control groups and VR groups, but also discovered that VR shows positive trends for increasing perceived levels of preparedness (Smith and Hamilton, 2015).

The possible equivalence between VR and traditional methods shows that VR is powerful as a self-learning tool to complement teaching in nursing (Chang and Lai, 2021). However, the successful use of VR as a teaching tool in nursing is influenced by how the application and the interactions are designed and the user experience it can provide. Empirical evidence of this is shown for instance in Chang and Lai (2021), Komizunai et al. (2020), Botha et al. (2020), and Choi (2019) which illustrate how design limitations in the applications affect how users experience the simulation. For instance, Chang and Lai (2021) identify the lack of realism in the simulation as a key theme whilst Choi (2019) found that interaction through controllers limits the authenticity of the simulation.

3. Methodology

The Nursing XR application was developed following Gilardi et al.'s (2021) process (see figure 1), which requires a close collaboration between faculty experts, students, and developers.

The pre-design and design stages of Gilardi et al. (2021) are grounded in participatory design (Sears et al., 2007). Vasilchenko et al. (2020) advocate participatory design as an approach that extends to multiple levels of people interaction promoting creativity, reflection, and collaboration. Based on these principles the project involved partnership and collaboration with students, industry, and academics.

An initial blue sky thinking process between the Co-Is (nursing experts) and the Project Lead (XR expert) was used to identify the needs for the nursing programme, identifying the broad areas of decision making, and wound dressing as suitable for XR development and as an area that would benefit the current delivery of nursing programmes.

Following ethical approval, student nurses enrolled in part 2 and 3 on the BSc and MSc Adult and Mental Health nursing at the University of the West of Scotland were invited to participate in an online interactive workshop aimed at gathering students and faculty needs. Ten student nurses responded to the workshop advert and attended the session. In addition to the student nurses, two lecturers in nursing from two different Universities (Co-Is), the PI and developers from the company used for the software development participated in the workshop.

The online workshop combined: knowledge scoping activities, aimed at understanding students familiarity with the subject; barriers and facilitators scoping, aimed at identifying the students' needs and current best practice; blue sky brainstorming activities, aimed at understanding the student vision for the application integration within the teaching programme. The workshop was concluded by a nominal group consensus activity in which findings were discussed and classified based on impact on learning and desirability of adoption. The workshop allowed the faculty to understand student needs and to initially identify where the application could be integrated within the programme. It also helped consolidate the notion that experiential learning (Kolb, 2015) should be the main pedagogical theory that underpins the project.

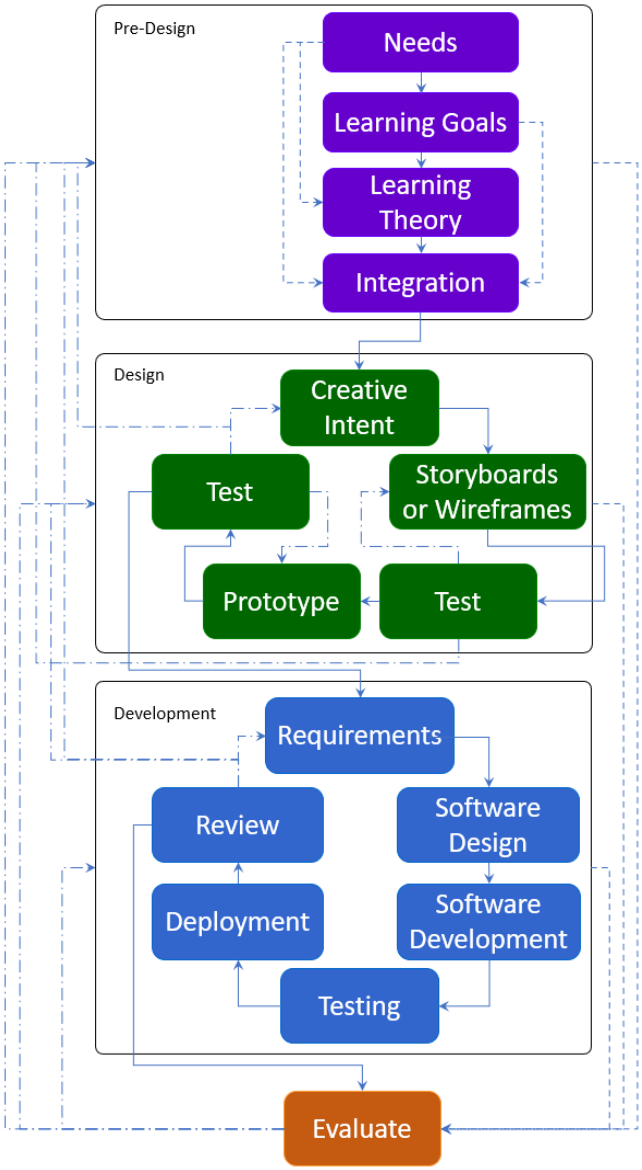


Figure 1: Design process from Gilardi et al. (2021)

Workshop outcomes were used as input for a co-design approach to the scenario development between the faculty experts and the company development team. The resulting scenario and branching narrative were used to guide the development of the application. An initial evaluation with the pre-alpha version of the software was undertaken, the session consisted of three students and two faculty (Co-Is) undergoing a playthrough of the VR scenario observed by the PI, which took notes of the emerging behaviours during the playthrough and moderated a focus group with the participants.

4. Designing Nursing XR

In this section the design and development process followed will be mapped on the Gilardi et al.'s (2021) process shown in figure 1.

4.1.1 Pre-Design

In preparation for the design workshop with students the two nurse lecturers documented the process of wound management guided by best practice guidelines. The Nursing and Midwifery Council (NMC) Future Nurse Standards (NMC, 2018) outline the minimum requirements of a registered nurse and form the basis of all nursing programmes within the UK. The standards set out key skills and competencies which centre around communication, decision making and safe effective care. In addition to the NMC standards there is a wealth of best practice guidelines, pathways and frameworks which support students and registered nurses to make

clinical decisions, thus enabling them to develop and advance their knowledge and skills in the field (NMC, 2018; Lister et al., 2021; Clinicalskills.net, 2022).

This initial process of documentation identified the problem definition and examined the learning and teaching objectives within the current curriculum. This established a working outline of the process for the team and decision points and stages to help prompt the students during the workshop.

The workshop began with an introduction to XR and the overarching aim of the project to develop experiential learning for nursing students to teach how to perform assessment and decision making about patients through a wound dressing scenario. During the workshop, the participants developed a storyboard displaying their knowledge of the patient journey and how to undertake a wound dressing, see figure 2.

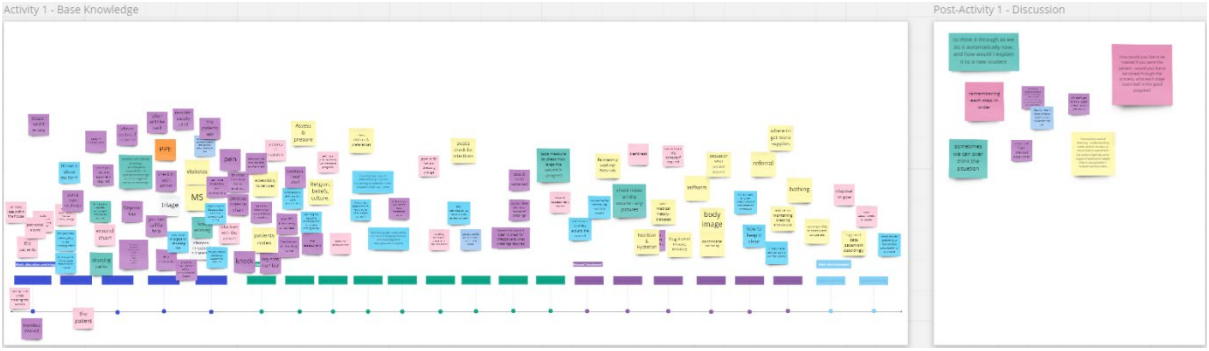


Figure 2: Patient journey timeline developed by the students during the workshop.

This captured the elements of workflow that were less understood and key decision points to be integrated into the Nursing XR scenario. Students reflected on finding it difficult to remember all the steps of the patient journey and this was related to their preference to a kinetic approach to learning and limited exposure to wound management in clinical practice. Notably all students spoke about visualising how to undertake the process and the communication and decision-making skills they would use at different points. The students identified low confidence as a key theme in this workshop, in terms of exposure to wound assessment and management in real life and in terms of using XR technology. Involvement in the XR scenario design was viewed by the students as helping them to develop the knowledge, skills, and confidence to feel prepared going into real life situations and to be confident communicating with practice supervisors and patients. In principle the students voiced that the aim of the project was innovative and would be useful in their learning particularly applying theory to practice.

4.1.2 Design

The preparation work undertaken for the workshop discussed in 4.1.1 was used to outline the process and decision-making points to the design and development team. It also formed the basis for the scenario development and the process of designing three-dimensional spaces and interactions within the VR application through paper wireframes and low fidelity prototypes.

An authentic scenario was developed based on clinical practice in a community setting and was underpinned by the best available research. In the development of the scenario, a branching narrative was applied to illustrate the range of unfolding actions and decisions of the student, which consequently results in an array of endpoints or outcomes for the patient (Riedl & Young, 2006). In concordance with the method of branching narrative, variation was scripted at this design stage in anticipation of the potential requirements and decisions of the user (Verkuyl et al, 2019). The participatory design approach mentioned in section 3 continued between the lecturers and learning technologists to shape and review the narrative, ensuring the content mirrored the patient's journey, decision points, safe practice, and current research and clinical guidelines. In addition, when integrating the branching narrative into the product design, cognisance was taken to ensure accessibility and learning needs of the user were incorporated. This included but was not exclusive to, verbal and written narrative, pictures, videos, access to decision support throughout the scenario and an introductory tutorial to aid digital literacy. To have a joint understanding and sharing of common language the lecturers created a wound in the simulation lab and distributed key documents and photos to illustrate the clinical activity the students would be engaged in. This enabled the designers to grasp the complexity of the procedure and scale of individual objects required

within the XR environment resulting in a scenario composed by three main stages: triage room, where students prioritise participants and gather the material they need for the patient visit, patient house, where the students holistically assess the patient behaviour, their environment and make decisions on the treatment of the wound, and finally the triage room again where they are debriefed on their performance.

The information gathered to prepare for the workshop and the results from the workshop were integrated to develop a series of paper prototypes in the form of 360 wireframes, see figure 3 left.

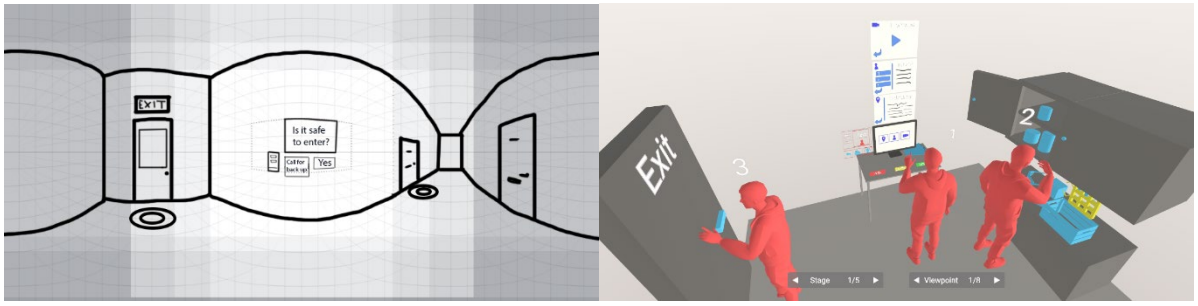


Figure 3 Left: Low fidelity paper wireframe of the corridor scene, where students have to make the decision whether the environment is safe to enter, 360 interactive version here; Right: mid- fidelity prototype of the triage room developed in ShapesXR.

The paper wireframes were used to elicit requirements from the lecturers enabling them to discuss specific interactions and functionalities that should appear in the final application. The wireframes further showed how the environment would look and feel, but also, how different actions could take place by rapidly sketching and modifying the designs and displaying them in 360; thus, providing a sense of space and ability to pre-visualise the scene in VR. This was achieved by using an equirectangular grid template upon which sketches were drawn at each application stage. The sketches were then embedded into a webpage using the A-Frame Web XR framework. UI 'hotspot' elements were placed on the different sections of the wireframes to highlight interactions, affordances, and waypoints. The wireframes provided an effective approach to test and validate the conceptual design of the experience and effectively elicit requirements and feedback from the faculty experts.

Once the initial design ideas were validated, mid-fidelity prototypes of each scene were developed using ShapesXR (figure 3 right). ShapesXR is a VR application designed to develop three-dimensional prototypes in VR. Using a VR application to design VR experiences allowed the designers to iterate through their design process and test with the faculty experts. The participatory design experience at this stage took place by being immersed within the mid-fidelity prototype, resulting in very quick alterations and iterations of the initial design choices and provided more options for discussing both usability and aesthetic features. When each prototype was validated with the faculty experts, the mid-fidelity designs were exported into Unity, providing the starting point for development.

4.2 Development

The development followed a scrum agile process (Schwaber, 2004). The application was developed in the Unity Engine targeting Meta Quest 2 devices using the XR Interaction Toolkit (XRIT) and designed to be played in a seated position. The XRIT provides VR camera rig, action-based input, object interaction and haptic/visual feedback components which enable development of fully immersive experiences. With the various types of user actions required to simulate the experience, we extended the functionality of the components provided in the XRIT adding a body anchored inventory system, gesture based, and non-diegetic and diegetic interfaces, figure 4. To produce the simulated patient, a 3D character model was generated. The experience composed of three embedded interfaces; a smartphone, touchscreen computer, and inventory bag all of which are interacted with using a mix of diegetic interactions and graphical user interfaces. Touch input for these interfaces was simulated through raycasting from the player's index finger when their physical index finger is extended and checking for collisions between the raycast and an interactable interface element.



Figure 4: Three screenshots from the VR App showing non diegetic (tutorial and conversation choices) and diegetic interfaces (bag and medical equipment) used throughout the app.

5. Initial Evaluation

An initial qualitative evaluation of the pre-alpha application was performed with students and faculty experts. The ten students that took part in the pre-design workshop were invited to evaluation session, only three students responded to the call, the two faculty experts also took part in the evaluation as they did not experience the VR application before the session. The session consisted of a playthrough of the scenario and observation of participants during the playthrough, including note taking; resulting in a post-playthrough focus group. During the playthrough session the impact of interaction design on the experience evidenced in Chang and Lai (2021), Komizunai et al. (2020), Botha et al. (2020), and Choi (2019) was observed. Students and faculty had difficulties in understanding the mapping of the controllers and several bugs interfered with immersion and presence. As the pre-alpha did not have a tutorial for the controllers, it was observed that, participants tended to move around the space by moving with the wheeled office chairs instead of teleporting in the VR application. This caused participants to collide with each other and elements of the environment, forcing the principal investigator to intervene and reposition participants back to their original location. This was an interesting behaviour from the usability point of view and highlighted the importance of clear navigation interactions within the application. Other unexpected issues were observed with the body anchored system, some participants with a large body shape were unable to reach the body sockets of the virtual nurse to anchor tablet, bag, or ID card to it, causing the participants to push the controllers into their body in an attempt to reach the sockets.

The application was designed as single player and to be delivered to students in a shared physical space. Interesting communication behaviours emerged between students while they were in the application. During the triage stage, students started discussing the patients with each other and agreed on a course of action, which mirrors the decision making and teamwork that takes place within clinical practice. During the visit to the patient house, students discussed the environment and how they could undertake a risk assessment and interpret the environment to identify if the patient was coping and potentially required further care intervention and support. As such communication skills development was achieved in two ways: in-application, through the selection of different conversation snippets that allowed students to interact with the non-player character and reflect on what is the best approach to talk to patients; and in-real-life, through interaction with peers within the same physical room, discussing the scenario as they progressed through it.

The playthrough session was followed by a focus group, which was audio recorded and transcribed. Participants appreciated the realism of the environment and tasks:

> *"It's quite realistic as well. [...] I personally felt I was back on a placement at a patient's door thinking I should do this before I go in, I should ask this before I go in"* – Participant 2

> *"I thought, was quite real I felt quite immersed in the experience, there was a couple of things that felt natural for me, you know, when I was moving around the room and I got to the home..."* – Participant 4

However, they noted how the current bugs and their inexperience with using VR controllers distracted them from the scenario. This was expected as the software was still in pre-alpha. To overcome their inexperience with VR, participants suggested a preparatory VR session to allow them to familiarise themselves with the controls before using it in the class.

Participants also felt that when in the experience they should play the role in full:

> *"I thought of myself as a nurse, and what steps I should be taking before I make any other steps. And just ensure that I've kind of covered everything before moving on to the next step."* – Participant 2

Participants also felt that it could supplement their placement with experiences they would not otherwise be exposed to:

> *"Yeah, I've only had mental health placements so far, but you don't really see wounds much. I've not seen them much at all actually. And placement terms, I don't know. It depends where you get your placement. And it depends to patients that are obviously admitted and stuff. So, I don't know how many unless you are on general placement you see that. So, it'd be good for the mental health side of things, if you don't see it on placement."* – Participant 3

Student were asked whether they see this as beneficial for their learning. They felt that the application was valuable, and the immersion and presence induced by the application was beneficial to their learning. Participants felt they had a safe space to experiment and learn without feeling judged, while at the same time had the ability to discuss decision making and interactions with their peers. This prompted reflection on the experience of simulated practice, as this extract of conversation between two student participants highlights:

> *"Participant 01 - I actually think it's really good. [...] Because it takes you away. You can hear other people, but they're not part of what you're doing. If you're not like...*
>
> *Participant 2 (interrupting Participant 01) - I totally agree with that, I can be quite anxious at times and quite aware of my surroundings and shy and things. Some people might not gonna come out their shell. But again, with that on, you're in a different environment altogether I felt and didn't feel as if I was going to holding them back from shouting or seeing anything around asking a question. It was...*
>
> *Participant 01 (interrupting Participant 02) - and nobody can see what you are doing, they cannot see you are making a mess. [...] it's good in that sense that you can learn at your own pace without feeling pressure without people watching you"*

Finally, student participants were asked where they would see the application integrated within the programme. Participant 01 expressed firmly:

> *"It's got to be under skills lab. Because this is something you're doing, you're getting shown how to do CPR on someone that's just as important going to somebody's house that needs a dressing changed a few times a week […]."*- Participant 01

This led onto students brainstorming how Nursing XR could integrate theory and skills lab sessions, for example:

> *"I could see it, put your stuff on and then go into the simulation (Nursing XR). And do it that way. I can see it tying in with that"* - Participant 04

Students highlighted that this would complement their practical skills development through the integration of theory and simulated practice, identifying that Nursing XR could be used throughout the progression of the programme to develop and consolidate their learning.

6. Conclusions

This paper adds to the growing body of evidence in the application of XR for teaching. The implementation and evaluation of Gilardi et al.'s (2021) design and development process has shown to be an effective model in the creation of Nursing XR, a VR application for wound management and assessment for student nurses.

Gilardi et al.'s (2021) is rooted in participatory design. The value of working across disciplines and with the end user created the conditions for shared understanding of needs and outcomes, clarity of professional languages, and collaborative learning. Ultimately this resulted in a product which met the intended aims of facilitating simulated nursing practice and developing student nurses' skills, as well as identifying where and how the resulting VR application can be integrated within the Nursing programme.

Incidental learning also emerged throughout the project, particularly from testing and evaluation, which provided insight into user ability and the physical learning environment. Nursing XR not only provided students with an opportunity to undertake decision making, risk assessment and wound management, but also elicited collaboration and discussion on prioritization of patients, treatments, and holistic assessment of the patient environment through peer discussion between students in the same physical room while immersed in the VR application.

Gilardi et al.'s (2021) process was shown to be viable and effective for XR application development and adaptable and transferrable to nursing education and simulation. Future work needs to take account of the monetary and staff resources required for the participatory development, which are high and resource intensive. However, these can be reduced through agreement of IP ownership between developers and clients.

The gamification aspects of the project are yet to be implemented and will consist of a scoring system for actions undertaken during the scenario and reflection points through questions embedded within the environment.

Considering the incidental learning from the project, future work will consider potential research into the physical learning environment in which VR applications are used. A thorough evaluation of the benefits of the application will be undertaken as next step for this project.

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Serious Games as Innovative Formative Assessment Tools for Programming in Higher Education

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Abstract: Serious games are becoming increasingly popular as alternative supplementary learning approaches across all disciplines at all levels. Learners are more enabled to become more actively involved, not only in the learning process but also in the design and development of innovative formative assessment tools. This paper will present four serious games for programming education developed as part of a Serious Games honours year module in Higher Education at the University of the West of Scotland. Computer Games Development students were tasked as part of a research project to design and implement a serious game for students in their course or other Computer Science related courses in earlier years to provide their peers with innovative games for the purposes of formative assessment. It was hoped that the participants could enhance the engagement of courses that they had already passed but also utilise their creative Games Development skills in a new productive way to enhance the assessments in their own course having had the experience. Permitting students to design their own formative serious game assessments in this way enabled enhanced creativity with the students creatively tackling the overall problem in insightful and surprising ways. This paper will look at four games created for the purposes of teaching programming by analysing the overall learning outcomes, development process and providing a description of the games. The idea is to provide insight into the development process of serious games for programming education in terms of similarities, differences and to produce a basic framework for development in relation to content, assessment, and game mechanics. The paper will produce an overview of the excellent games created and present a case for increased active involvement of students to develop their own serious games – particularly on Computer Games degree or college courses.

Keywords: games-based learning; formative assessment; programming; Higher Education; serious game

1. Introduction

Programming is a very complex skill requiring years to master and is a contributory factor of the high levels of attrition experienced on Computer Science related courses. Moreover, Software Engineering graduates have a reputation for being under prepared for industry indicating that new novel teaching approaches should be investigated beyond the traditional lectures, tutorials, and labs extensively utilised. This is particularly true now as we enter a post-pandemic age of hybrid delivery. According to the Young Scot Report *"young people have a significant stake in how assessments need to change to reflect our future society and economy.*" In relation to inclusivity and accessibility, online resources need to change in relation to interactivity by providing games that can assess levels of knowledge and support progress (SQA, 2018). With this in mind Computer Games Development students in Higher Education are in a unique position to develop gamified, innovative formative assessments for courses that they have had high levels of experience in. Not only should learners have a say in the assessments that they are undertaking but also a direct role in developing these assessments. Computer Games students undertaking a final year Serious Games module were tasked with the objective of developing gamified innovative formative assessments for courses they had undertaken in earlier years of their course. This allowed application of their game development skills in a highly focused way and allowed the learners themselves to utilise their creativity, innovation, ingenuity in parallel with their course related knowledge. This paper will present a detailed description of four games for programming education that were developed and perform a basic comparison of learning outcomes, and game mechanics integrated in relation to pedagogy utilising the Learning Mechanics-Game Mechanics model, genre, and implementation/format.

2. Previous Work

Serious games have a rich history (Boyle, Hainey and Boyle, 2021) have been used for educational and training purposes in a number of diverse areas and have become an exceptionally popular research topic worldwide

particularly in the last two decades (Schöbel, Saqr, and Janson, 2021). Zyda (2005) defines a serious game as *"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."* Developing a serious game is multidisciplinary challenge involving theory or cognition, pedagogy, flow, motivation, game design story, goals, rules, and content (Bellotti et al., 2013). Serious games have now become so ubiquitous that there are taxonomies for different types of serious game in different disciplines e.g., a taxonomy of games in Science Education (Magnussen, 2014) categorising games into:

- **Training games** – designed to train skills through repetition of individual exercises.
- **Inquiry Games** – focusing on scientific inquiry, gathering data, formulating hypotheses and building arguments.
- **Professional simulation/epistemic games** – gamers role play scientific or technical professions.
- **Embodies system games** – focussing on the manipulation of scientific phenomena.
- **Research collaboration games** – focussing on high-level scientific research and technical development.

Frameworks also exist for the integration of serious games into companies (Azadegan, Riedel and Baalsrud Hauge, 2012). There are also general classification taxonomies (e.g., Djaouti, Alvarez, and Jessel, 2011) where one in particular classifies serious games in terms of:

- **Application** – Education, Well-being, Training, Advertisement, Interpersonal Communication, Health Care and Others.
- **Activity** – Physical exertion, Physiological, Mental.
- **Modality** – Visual, Auditory, Haptic, Small, Others.
- **Interaction style** – Keyboard/mouse, Movement tracking, Tangible interfaces, Brain interface, Eye gaze, Joystick, Others.
- **Environment** – Social presence, Mixed reality, Virtual Environment, 2D/3D, Location awareness, Mobility, Other (Laamarti, Eid, and el Saddik,2014).

Effective game story and narratives are also considered to be highly important for serious games to promote learning with the following contributing constituents identified by Naul and Liu (2020):

- **Distribute narrative** – the narrative is placed throughout the entire game via environmental storytelling and is not isolated in one place.
- **Endogenous fantasy and intrinsic motivation** – inextricably interconnecting the fantasy with the learning outcomes is more conducive to intrinsic motivation meaning that if the player is motivated by the fantasy, then they will be motivated by the learning.
- **Empathetic characters and virtual agents** – relatable and powerful characters have the power to influence attitudes and decisions more effectively.
- **Adaptive and responsive storytelling** – This is where learners and gamers in general are more compelled by stories that are customised to them.

Research has been performed to produce a framework to map game mechanics to learning mechanics utilising Bloom's ORDERED thinking skills (Arnab *et al*., 2014). The existing research indicates that there are many attempts to classify serious games in relation to discipline, application, interactivity, format, game mechanic and educational content. This paper is primarily concerned with programming education and there have been a large number of serious games developed within Computer Science for that purpose. Miljanovic and Bradbury (2018) performed a review of 49 serious games for programming and categorised them in relation to educational content:

- **Algorithms and Design** – algorithmic comparison, problem solving.
- **Fundamental Programming Concepts** – non-specific programming concepts, syntax and semantics, variable and primitive data variables, expressions and assignments, input and output, conditionals and iteratives, functions and parameters, recursion.
- **Fundamental Data Structures** – arrays, heterogeneous aggregates, string processing and abstract data types.
- **Development methods** – program comprehension, debugging strategies and documentation and program style.
- **Software Design** – Object Oriented Design Paradigms.

One particular problem that is identified is that as a result of serious programming games being independently developed this does not take into account lessons learned from existing games. Suitable evaluation also has to be conducted in relation to appropriate validation. This paper will attempt to categorise and describe 4 programming games utilising a compiled serious games framework using:

- Learning outcomes (Hainey, 2010)
- Science education categorisation (Magnussen, 2014).
- Game mechanics integrated in relation to pedagogy utilising the Learning Mechanics-Game Mechanics model (LM-GM model) (Arnab *et al*., 2014).
- General classification (Laamarti, Eid, and el Saddik,2014).
- Story, Narrative (Naul and Liu, 2020)
- Educational content (Miljanovic and Bradbury, 2018).

The games will be overviewed methodically utilised the following compiled framework shown diagrammatically in Figure 1.

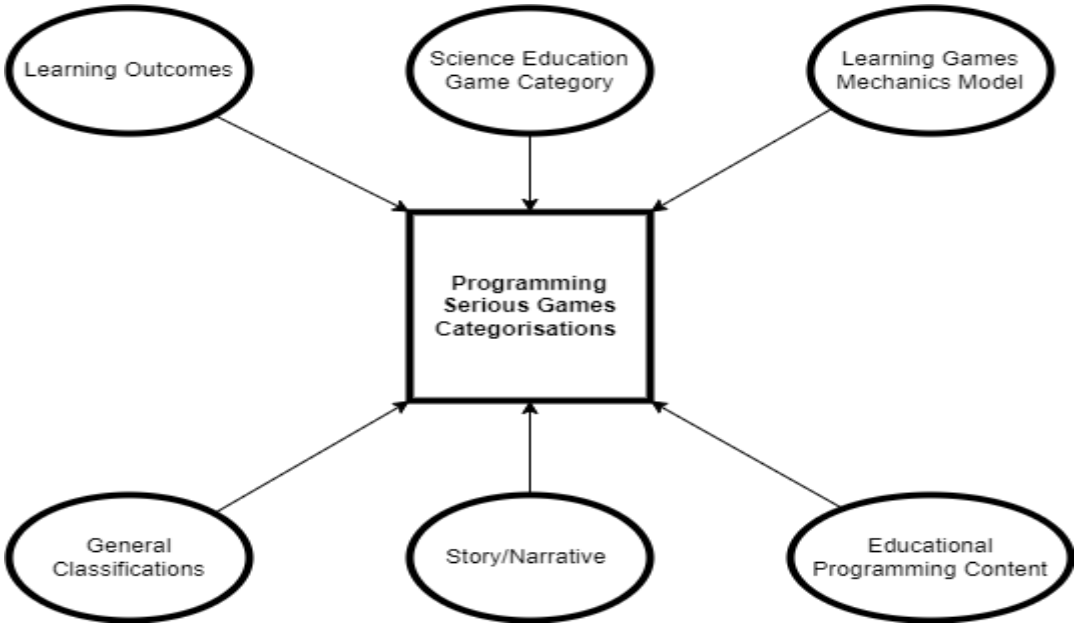


Figure 1: Compiled categorisation framework

3. Programming Games Developed

The games were developed as part of a final year Serious Games course at the University of the West of Scotland as part of a Vice Chancellors Innovation Research Grant. The idea was to utilise the most valuable and underutilised stakeholders in relation to producing innovative formative assessments for supplementary learning – the students themselves. It allowed them to reflect on their graduate capabilities and consider the types of games that they would like to have had during courses that they had already passed and to consider innovative ways to teach lower-level undergraduates in their course. The four programming games selected achieved the highest grades in the course and utilised endogenous fantasy coupled with creative mechanisms to fully integrate fun, immersion, and engagement beyond a formative/summative quiz. We will also use this study to stringently and thoroughly categorise these games to refine the categorisation/methodological framework can be used in the future and further refined.

3.1 Game 1: OOPs: Object-Oriented Problems

Description: The game allows you to be in charge of a Virtual Museum of OOP where some damage has been done and this is then rectified by the player answer all of the questions correctly i.e., restoring all of the missing information. Figure 2 shows screenshots of OOPs.

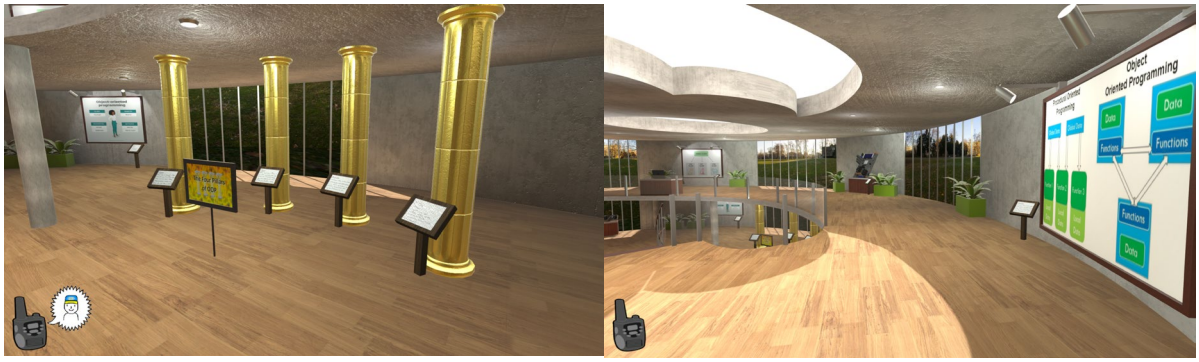


Figure 2: Screen shots of OOP

3.1.1 Learning outcomes

- To understand the core concepts of object-oriented programming
- Identify and describe the four pillars of object-oriented programming
- Teach users how to define various object-oriented programming concepts
- To develop a knowledge of useful object-oriented programming techniques
- To develop understanding of writing object-oriented programs that combine functions and data

Science Education Game Categorisation(s): Professional simulation/epistemic games

Features in the LM-GM model

Game Mechanics	Implementation	Thinking Skills	Learning Mechanics
Ownership. Protégé Effect	**Through story and the fact that the game is a Virtual Museum**	**CREATING**	Ownership, Responsibility
Action Points	**Various exhibits**	**EVALUATING**	Assessment, Motivation
Feedback, Realism	**Q and A with historical programming exhibits**	**ANALYSING**	Analyse, Identify, Feedback
Movement, Selecting/Collecting	**Free movement through the 3D environment**	**APPLYING**	Demonstration
Role-play, Tutorial	**Assuming the curator role and a tutorial example**	**UNDERSTANDING**	Participation/Questions and Answers, Tutorial
Cut scenes/Story	**Tutorial cut scene at the beginning**	**RETENTION**	Guidance, Explore, Discover

3.1.2 General classification

Application – Education, **Activity** – Mental, **Modality** – Visual, Auditory, **Interaction style** – Keyboard/mouse, **Environment** – Virtual Environment, 3D, **Genre:** Virtual Museum. **Implementation:** Unity Engine

Story and Narrative – The story and narrative are utilised in this implementation to set the scene where a cut sequence is played at the beginning showing damage and destruction to the museum exhibits. It is then up to the player to restore the exhibits and the information/knowledge contained therein by arranging all the exhibits in response to the auditory scaffolding. In terms of the classifications of story and narrative the game utilises: **distribute narrative, endogenous fantasy and intrinsic motivation and empathetic characters and virtual agents.**

Educational content – The educational content includes main principles of Object-Oriented Programming (OOP) (encapsulation, inheritance, polymorphism, and abstraction). The origins of OOP, Object Scope, Features of OOP, Types of class, passing classes, defining classes, the meaning of polymorphism, classes using encapsulation, structuring arrays, the keyword used to describe static variables and the first purely OOP language developed. The classification is really software design

3.2 Game 2: Planet Edolia

3.2.1 Description

The game begins with the player in a compromising position, and it becomes apparent that they have to make their way through a Jurassic Park like enclosure by using their coding/dinosaur knowledge to open the gates with a T-Rex in pursuit. Figure 3 shows screenshots of Planet Edolia.

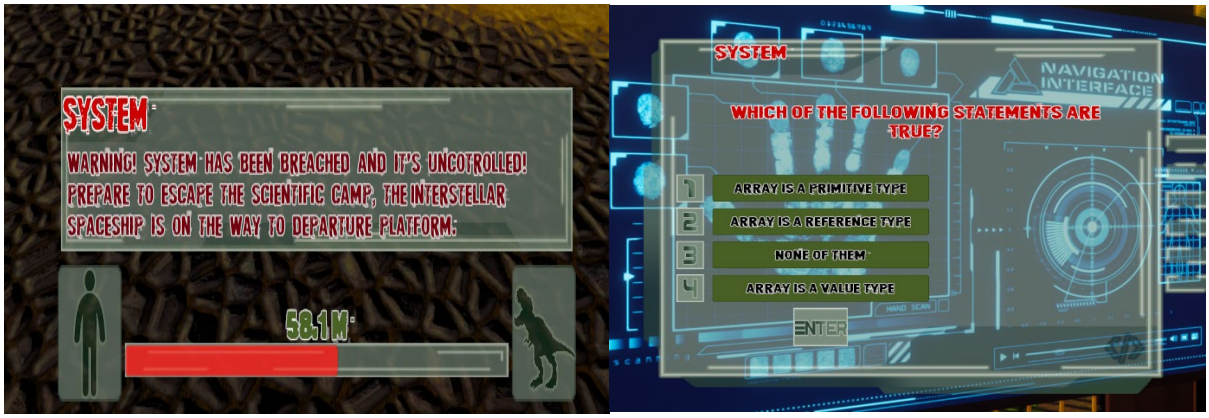


Figure 3: Screenshots of Planet Edolia

3.2.2 Learning outcomes

- Overall knowledge of C#
- Coding syntax
- Object Oriented Programming
- Problem and critical thinking skills.
- Informative information about the dinosaurs

Science Education Game Categorisation(s): Professional simulation/epistemic games

Features in the LM-GM model

Game Mechanics	Implementation	Thinking Skills	Learning Mechanics
Ownership, Status	**Through the situation presented in the game i.e., escape from a Dinosaur enclosure with a T-Rex in pursuit.**	**CREATING**	Ownership, Responsibility
Action Points, Game Turns	**Various gates have to be opened via quiz entering the correct answers**	**EVALUATING**	Assessment, Motivation, Incentive.
Feedback, Realism	**Questions and answers with consequences i.e., the imminent pursuit.**	**ANALYSING**	Analyse, Identify, Feedback
Movement, Selecting/Collecting, Progression, Capture Elimination, Time pressure.	**Movement through a particular route selecting particular answers to progress in a pressurized timeframe.**	**APPLYING**	Demonstration, Action/Task,
Role-play, questions, and answers	**Assuming the role of the curator and a tutorial example**	**UNDERSTANDING**	Participation/Questions and Answers, Tutorial
Cut scenes/Story, Pavlovian Interactions	**Tutorial cut scene at the beginning**	**RETENTION**	Guidance, Explore, Discover

General classification

- **Application** – Education, **Activity** – Mental, **Modality** – Visual, Auditory, **Interaction style** – Keyboard/mouse, **Environment** – Virtual Environment, 3D, **Genre:** 3D RPG/Puzzle, **Implementation:** Unity Engine

Story and Narrative - The story begins with the player in Dinosaur enclosure, and they are told that the T-Rex will be released in 1 minute, giving the opportunity for them to quickly explore and devise a solution. In terms of the classification the game utilises distribute narrative, endogenous fantasy and intrinsic motivation and empathetic characters and virtual agents.

Educational content - The educational content includes main principles of Object-Oriented Programming (OOP) (encapsulation, inheritance, polymorphism, and abstraction). The origins of OOP, Object Scope, Features of OOP, Types of class, passing classes, defining classes, the meaning of polymorphism, classes using encapsulation, structuring arrays, the keyword used to describe static variables and the first purely OOP language developed. The identified category is software design.

3.3 Game 3: Coder-Bot

Description – The game sets the scene by telling the player that they have to assist in producing an antivirus and allows progression of the Coder-Bot through the levels with a drag and drop sequence of programming constructs. After the code is executed, you then see the result of the coding commands. Figure 4 shows screen shots of Coder-Bot.

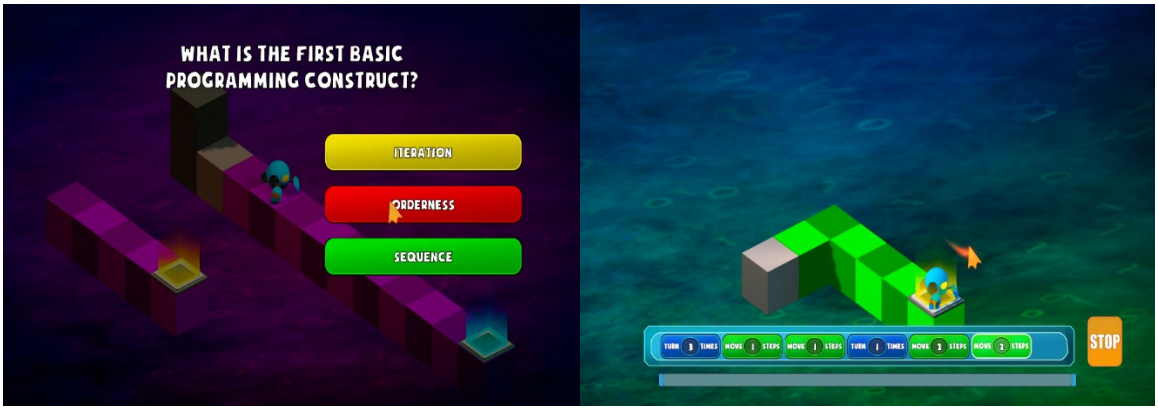


Figure 4: Screen shots of Coder-Bot

Learning outcomes

- Identify and describe the three basic programming constructs.
- Understand the importance of sequence and the consequences of an incorrect order.
- Explain the purpose of selection and when best to use it.
- Recognise the different types of iteration and prevent infinite loops.
- Apply the three basic programming constructs to solve puzzles.

Science Education Game Categorisation – Professional simulation/epistemic games, Embodies system games

Features in the LM-GM model

Game Mechanics	Implementation	Thinking Skills	Learning Mechanics
Ownership, Status, Design Editing, Protégé effect, strategy/planning, Tiles/Grids	Narrative sets the scene in terms of locating an anti-virus alongside a scaffolding companion to plan through a tile and grid environment using coding constructs	**CREATING**	Ownership, Planning Responsibility, Accountability
Action Points, Game Turns, Assessment, Rewards/penalties	Points have to be reached using programming directions or the player falls off the edge.	**EVALUATING**	Assessment, Motivation, Incentive.
Feedback, Realism	Creating a plan and programming script and then executing it. If incorrect the player does not reach the destination.	**ANALYSING**	Analyse, Identify, Feedback, experimentation, feedback, observation.
Movement, Selecting/Collecting,	Movement through a particular route selecting particular answers to progress in a pressurized timeframe.	**APPLYING**	Demonstration, Simulation.

Game Mechanics	Implementation	Thinking Skills	Learning Mechanics
Progression, Capture Elimination.			
Role-play, Cascading information.	Assuming the role of a coder to successfully navigate a bot using an elongated script.	**UNDERSTANDING**	Participation.
Behavioural momentum.	Once the script is executed you see the results of the simulation	**RETENTION**	Generalisation, repetition, discover, explore, guidance, instruction.

General classification

- **Application** – Education, **Activity** – Mental, **Modality** – Visual, Auditory, **Interaction style** – Keyboard/mouse, **Environment** – Virtual Environment, 3D, **Genre:** 3D isometric puzzle game, **Implementation:** Unity Engine

Story and Narrative - The story sets the scene for the problem by asking for your name and then enlisting your help to navigate a series of levels to get the computer antivirus and defeat Dr. Syntax. The game uses: distribute narrative, endogenous fantasy and intrinsic motivation and empathetic characters and virtual agents and adaptive and responsive storytelling.

Educational content - Sequence, Iteration and Selection - fundamental programming concepts.

3.4 Game 4: LearnToCode

3.4.1 Game description

The implementation contains six mini-games for various different aspects of programming including: Ball game where the player alters a boolean value to open a door to allow a ball to progress as well as editing the velocity to see how fast it needs to go to reach the appropriate teleporter utilising a degree of trial and error. 3rd person driver allowing the player to alter values associated with objects in the game to improve their gaming experience such as velocity of the car and the amount of petrol items that can be picked up to reach the end goal. Isometric Maze allowing the player to navigate through a maze with limited tries and a number of obstacles by identifying and removing coding structures such as collision boxes. Top-Down shooter allowing the player to actually play the game but also increase their health utilising the code and well as the moving speed and the projectiles fired in terms of number and semi-automatic/automatic. Tower Defence allowing the player to alter the aim of the towers against waves of enemies utilising code and becoming familiar with collision boxes. Endless runner allowing the player to alter the jump velocity to clear gaps and understand the basics of the deltatime functions in Unity. Figure 5(a) shows the Tower Defence mini-game and Figure 5 (b) shows 3rd person driver.

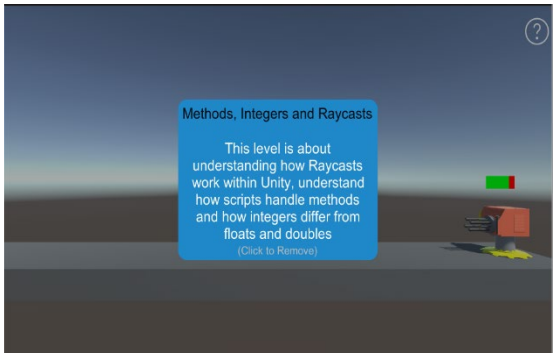


Figure 5(a): Tower Defence Game



Figure 5(b): 3rd Person Driver

3.4.2 Learning Outcomes

- Knowledge of fundamental programming concepts (Variables, Objects, Properties, Methods, Control Statements (if/else statements and loops))
- Knowledge of C#.
- Problem solving skills.

- Critical thinking skills.
- Ability to code in C# for the Unity engine.

Science Education Game Categorisation – Professional simulation/epistemic games, Embodies system games.

Features in the LM-GM model

Game Mechanics	Implementation	Thinking Skills	Learning Mechanics
Design, Editing, Ownership, Strategy, Planning	Simulation sets the scene with the puzzle/obstacle to be overcome.	**CREATING**	Accountability, Ownership, Planning, Responsibility.
Action Points, Rewards/penalties, assessment.	The game allows advancement to particular points through intervention and success and failure. The reward is progression.	**EVALUATING**	Assessment, Hypothesis, Incentive, Motivation.
Feedback	The results of the coding inputs and what happens on the screen.	**ANALYSING**	Analyse, Experimentation, Feedback. Identify, Observation.
Movement, Progression, Simulate/Response.	The code is entered, and the results are immediate on the screen.	**APPLYING**	Action/Task, Demonstration, Simulation
Role-play	All mini games are viewed in terms of you assuming the role of a puzzle solving programming.	**UNDERSTANDING**	Objectify, Participation, Tutorial.
Behavioural momentum	Cause and effect suitably demonstrated where alterations to the code are then materialised.	**RETENTION**	Discover, explore, generalise, repetition.

3.4.3 General classification

Application – Education, **Activity** – Mental, **Modality** – Visual, Auditory, **Interaction style** – Keyboard/mouse, **Environment** – Virtual Environment, 3D, **Genre:** 3D Puzzle Game, Endless Runner, 3D FP Car game, Isometric Maze, Tower Defence., **Implementation:** Unity Engine

Story and Narrative - The story is based on **endogenous fantasy and intrinsic motivation** by allowing players to observe a scenario and take corrective action.

Educational content **-** The educational content of this game falls into the following categories: Algorithms and Design, Fundamental Programming Concepts and Software Design

4. Conclusions

This paper is a celebration and academic showcasing of some of the highly innovative, creative, exciting, and outstanding serious games developed by students in a SCQF L10 module in Higher Education at the University of West of Scotland. The entire idea was to involve the most valuable and underutilised stakeholders in education i.e., the learners themselves to develop serious games as innovative formative assessment tools for other learners earlier on in their course.

One extremely interesting point to note is the way that the learners all used their creativity in different ways and despite the fact that we only analysed a very small subset of the games produced, there was a remarkable degree of versatility.

- One was a time-pressured Dinosaur maze game with an integrated quiz.
- One was a Virtual Museum of Object-Oriented Programming with integrated quiz, exhibits and completion tasks.
- One was a drag and drop code modification level traversal game and
- One was manipulating code to achieve more desirable outcomes in a particular context of a game and game genre.

A very rudimentary and preliminary categorisation framework was formulated from a discursive sweep of the literature to provide as much insight into the games as possible and work towards a framework for the

categorisation and development of serious programming games. This was a very useful exercise with some of the following revelations:

- It is highly likely that in terms of Science Education Game Categorisation, the majority of programming games will fall into Professional simulation/epistemic games and Embodies system games.
- The games adopt distribute narrative, endogenous fantasy and intrinsic motivation and empathetic characters and virtual agents with only one utilising adaptive and responsive storytelling which is far more difficult to implement. The four games in this study seem to integrate endogenous fantasy and intrinsic motivation as a minimum even if it simply altering variables to see the simulated effects.
- The framework used the LG-GM model which was exceptionally useful for deep analysis of the pedagogical effectiveness of the games and how this was going to be achieved. One particular aspect that Universities are concerned with is the idea of retention in their courses and only one of the games incorporated the majority of the learning mechanics for retention. Far closer and more specific consideration of pedagogical mechanics and content needs to be considered through recognised frameworks interconnecting game mechanics and pedagogy which is worthy of consideration in the design phase.
- In terms of general categorisations, the games were implemented in Unity. The Application was generally educational, activity was mental, modality was visual and auditory with the primary interaction style being keyboard/mouse and the environment being a Virtual Environment in 3D, with variable genres. One interesting part that this highlight is interaction and the possible requirement for adoption of new interactive approaches such as VR.
- Educational content was a mixture between fundamental programming concepts and software design which is also something to take into account when developing a programming serious game.

In terms of future directions and recommendations, the games have to be evaluated with learners to ascertain if they enhance, improve, and engage learners in the learning process. We also recommend that this has been a highly useful first study of its kind where Computer Game Development students have developed Serious Games for revision purposes on their own course and that this study should be repeated in other institutions as well as the University of the West of Scotland for the purposes of creating a Serious Games repository with a higher level of specialised focus. The specialised focus being that learners consider what particular revision tools they would have found useful at earlier levels in their course and implement them using their creativity and ingenuity. This ensures increased focus as one requirement for a successful serious game is the "*perfect knowledge of the learning domain to obtain the desired results*" (Barbosa et al., 2014). We will also develop the rudimentary framework into a workable set of guidelines for developing a serious programming game in terms of refinement. The main limitation of this mass innovative formative assessment production is that only really Computer Games Development and Technology students have the technical ability to implement games in general let alone games that require perfect knowledge of a learning domain with access to subject matter experts. In conclusion we do recommend that Computer Games Development courses running Serious Games or Games-Based Learning modules attempt this particular strategy of allowing their students to develop formative, innovative assessments for other learners at lower levels of the course. This makes the learners far more involved in the learning process in a holistic sense and is extremely worthwhile and illuminating process for educators.

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The Challenges of Designing Learning Games: Interviewing Professional Learning game Designers

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Abstract: The professional practice of designing digital learning games has existed for more than four decades. Even though considerable work has been done on research and development projects that include learning games (e.g., through Design-Based Research projects), there is relatively limited research on how professional learning game designers work, and what design challenges they face when trying to develop learning games for K-12 educational contexts. In this explorative interview study, we take a closer look at the design challenges that experienced learning game designers face during the design process, and what complexities and dilemmas they need to balance in doing so. The interview study is based on extended semi-structured interviews with five experienced learning game designers from five different learning game companies from Europe and the US. Having transcribed and coded the interview data, we conducted a thematic analysis to address the following research question: How do learning game designers experience and manage the different knowledge forms and design challenges that emerge when developing games for K-12 educational contexts? To answer this question, we draw on insights from design theory and domain theory, which allows us to map and analyse how the learning game designers try to establish links between different forms of knowledge across three domains: the pedagogical domain, the disciplinary domain, and the game design domain. Based on the thematic analysis, we identify three design principles across these domains, which are central to the learning game design process: 1) creating a shared language and repertoire for the involved actors (e.g., game designers, subject matter experts, and educational practitioners) across the three domains, 2) establishing meaningful links between educational aims and game elements, and 3) considering the educational context of the learning game. Addressing these design principles are all crucial, when engaging in the highly complex task of designing games for educational purposes.

Keywords: learning game design, domain theory, design theory, design challenges, K-12

1. Introduction

The professional development of digital learning games has been going on for more than four decades (Egenfeldt-Nielsen, 2005). In the beginning, learning games were based on simple designs, often based on simple skill and drill exercises or multiple-choice questions wrapped in primitive graphics and loose narratives. However, much has happened since the early days. Nowadays, digital learning game designers have a broad range of technological tools to choose from when creating new designs. Despite these technological developments, learning games have repeatedly been criticised for a lack of solid integration between game mechanics and learning goals, which may lead to poor learning outcomes. Several researchers have addressed this challenge when designing their own learning games. One example of this is Habgood and Ainsworth's (2011) study, which demonstrated the importance of ensuring meaningful integration of game mechanics with curricular knowledge to support the students' mathematical learning outcomes.

Despite the large body of research on games and learning, there exist relatively few studies on how professional learning game designers actually work and what challenges they face as a part of their professional practice. Designing learning games is a relatively complex process, which involves integration and use of expertise by actors from many different domains such as game developers, subject matter experts, and practitioners that are experienced in teaching the target domain of the game. In this way, the aim of the current study is to explore how professional learning game designers address the complexities of learning game design processes. Our research question is: *How do learning game designers experience and manage the interplay of different knowledge forms across domains that emerge when developing games for K-12 educational contexts?* To limit the scope of the study, we have focused only on design cases that relate to primary and secondary education (K-12). However, we will argue that our findings may also be relevant in relation to other target domains when design learning games.

2. State of the art

There exist several studies, which describe the development of digital learning games (de Freitas & Oliver, 2005; Kiili, 2005; Yusoff et al., 2009; de Freitas & Jarvis, 2009; Marne et al., 2012). The studies all show that the development of learning games is complex, and that many different types of knowledge are involved in the development process. This is also emphasised by Arnab and Clarke (2017), who presents a transdisciplinary methodology for developing learning games (or "serious games" as they call it). The model describes different phases of learning game development (pre-production stage, production stage, post-production stage), which each involves different steps such as mapping the learning goals of a game, the choice of methods for the design process, what experiences the game should create, how the game should be linked to the learning games etc. However, the model does not describe how the interdisciplinary collaboration can or should take place, or what challenges that such collaborations may create, which is the focus of the current paper. An interesting paper worth mentioning in this regard is Linderoth and Sjöblom's (2019) two case studies of learning game development at a national defence college and at a university course. The authors argue that learning game development benefits the most from the involvement of stakeholders, who both have pedagogical content knowledge and experience in game development.

3. Methodological approach

The study is a qualitative case study that involved interviews with learning game development companies who develop digital learning games or serious games. This involved extended semi-structured interviews with five experienced learning game designers from five different learning game companies spread out across Europe and the US.

The learning game designers were selected according to several criteria. First, we were mainly interested in interviewing experienced learning game designers. In this way, we only selected professional designers, who had or have had more than 10 years of experience as a leading role in a company that develops digital learning games or serious games. Moreover, we were interested in talking to designers, who had broad experience with learning game development. In this way, the learning game designers' areas of responsibilities should cover both organisational and practical development of learning games. We also ensured that the selected designers were willing to share experiences from their professional practice that included whatever challenges they had faced in the design process. Lastly, we decided that the designers should have a comparable academic background within the fields of game studies, education, or digital learning. This should ensure that the game designers would use the same shared language.

One of the authors interviewed the designers using a qualitative semi-structured interview guide (Brinkmann, 2013). All interviews focused on development of learning games with a specific focus on how the designers had worked with bridging the game development with the pedagogical content knowledge in the development process. The interviewees all reflected on and described how they involved professional participants from different domains within game development, subject matter content and when developing digital learning games. Before the interviews, each game designer was asked to select two learning games that they had designed for K-12 to secure reflections on specific games and create possibilities for comparison across the interviews. The interviews lasted from 48-106 minutes. All interviews were recorded, transcribed, and translated into English. See table 1 for an overview of the interviews.

Table 1: Overview of the interviews.

Informant	**Length**	**Context for interview**	**Information**
A	106 min.	Participant's workplace	CEO and founder of a learning game company. PhD in games and learning. Does sales and more client-oriented tasks. Starts the scope and concept phase.
B	48 min.	Online interview	CEO and founder of a learning game company. Holds a Master's degree in Educational Technology. Focuses on the financial parts of the company, marketing, HR, and administration.

Informant	Length	Context for interview	Information
C	59 min.	Online interview	Co-founder and Creative Director of a learning game company. Holds a Master's degree in Media Science. Does creative development, concepts, designs and production.
D	57 min.	Online interview	Self-employed and former Principal Designer at a learning game company. Holds a Master's degree in Entertainment Technology. Was in charge of managing the overall design process, pitching ideas and concepts to clients and establishing best practices when designing and developing learning games.
E	43 min.	Online interview	Owner, co-founder, and Creative Director of a learning company. Holds a Master's degree in Interaction Design. Does sales and more client-oriented tasks. Starts the scope and concept phase.

As illustrated in the table above the interviewees' both academic and professional background have a large range of similarities, including years as owner or founder of a learning game or serious game company. Furthermore, they have an average of 10 years in developing learning games. However, Informant D's professional background differs from the rest as this informant has not been the owner or founder of a larger learning game/serious game company. We still find this informant relevant as the criteria stated above is met.

It is important to highlight that one of the authors of this article has been working in informant A's company since 2020. All the interviews were conducted in 2021. To establish an open and honest interview situation, the other informants were informed by this professional relationship before conducting the interviews. However, the author's own position in the field and her professional relation to informant A may have influenced the data.

Having transcribed and coded the interview data, we conducted a thematic analysis (Braun & Clark, 2006) to answer our research question. The thematic analysis involved going through the following six steps: 1) Becoming familiar with the data through transcription, reading and re-reading the data, 2) Generating initial codes by coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code, 3) Searching for themes by collating codes into potential themes, gathering all data relevant to each potential theme, 4) Reviewing themes by checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic map of the analysis, 5) Defining and naming the themes by refining the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme, and 6) Producing the report, which include selection of vivid extract examples that relate back to the research question and relevant research literature. Based on the thematic analysis, we identified three analytic themes central to the learning game design process, which we will unfold in section 5.

4. Theoretical perspectives

In order to address and understand the challenges involved in designing learning games, we will use domain theory as an analytical lens (Hanghøj et al., 2018). According to domain theory, the design and use of games for learning are always enacted within and in relation to particular domains understood as "structured, patterned contexts", in which specific practices unfold (Barton & Hamilton, 2000, p. 11). Building on the domains identified by Hanghøj et al. (2018) and the design challenges described above, the specific domains involved in the process of designing learning games involve:

1. *Pedagogical domain*, which refer to how teachers conceptualise, adapt, and use games as a part of their pedagogical practices in a classroom context.
2. *Disciplinary domain*, which refer to specialised knowledge practices within disciplines such as mathematics, history or science, or expert knowledge of cross-curricular topics such as immigration or health, which may be embedded in a specific learning game.
3. *Game design domain*, which refers to the specialised practices of conceptualising and developing games.

We assume that the process of designing games for learning requires a complex interplay between these three domains, which often require negotiations and close alignment of different interests and knowledge types. As an example, it is often emphasised that learning game designers should strive for *endogenous* game designs,

where the learning aims is closely integrated with the game mechanics, in contrast to *exogenous* game design, where there is no or only limited link between the two aspects (Squire, 2006; Habgood & Ainsworth, 2011). Moreover, we assume that the process of designing learning games tends to involve different actors from three domains, e.g., teachers, subject-matter experts, and game designers. The relationship between the three domains is shown in Figure 1 below:

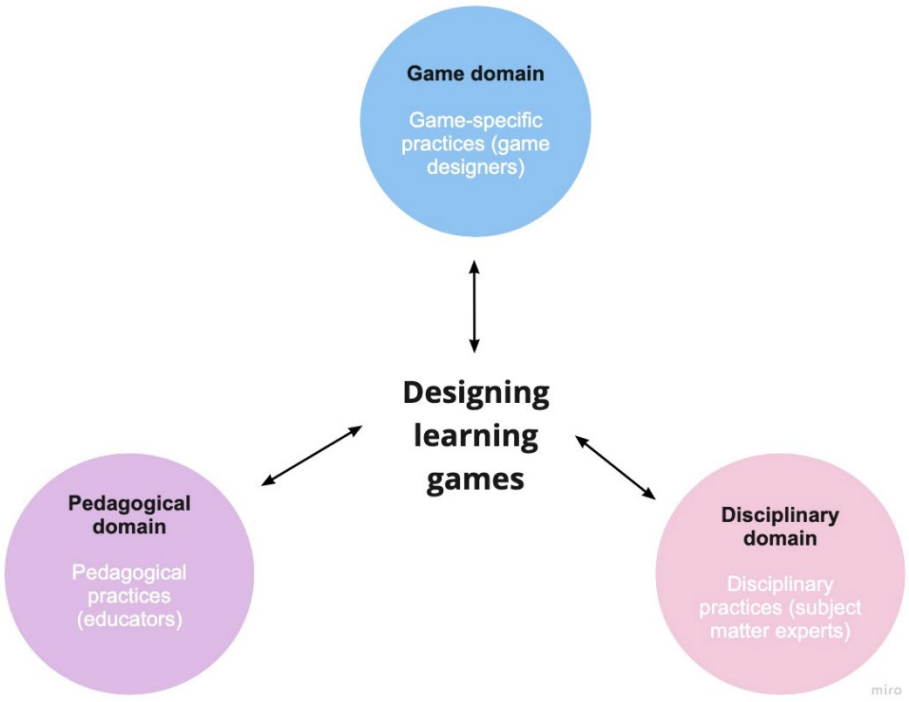


Figure 1: The domains involved in designing learning games

In practice, it may be difficult to draw clear boundaries between the three domains as they are often blurred, e.g., a teachers' use of a specific game in the pedagogical domain will also depend on the teachers' disciplinary understanding of the specific topic of the game. However, through the analysis we show that the three domains make sense as analytic and conceptual categories, which are all highly important to the learning game design process.

5. Analysis

We will now introduce the three themes, which we identified through our thematic analysis of the transcribed and coded interview data.

5.1 Theme 1: The trinity of designing learning games

Patterns across the interviews show that the design of a learning game calls for close involvement of actors across the three main domains - the game design domain, the pedagogical domain, and the disciplinary domain. As A describes it, someone must know how to design a game, someone must know something about the specific curricular content of the game, and someone must be knowledgeable about the context in which the game is going to be played.

C confirms A's statement about bringing together the subject matter experts, who hold the specialist content knowledge, the educators/teachers, and the game- and interaction designers. He argues that they form "the trinity of learning games" and that they need to be brought together in the beginning of the process and then touch base regularly to keep the process on track (Interview with C). This shows that it is key to involve actors from all three domains when designing a successful learning game. Each domain covers a range of different actors spanning from game designers to teachers and subject matter experts within a specific field. When developing a learning game, according to A and C it is essential to collaborate across the domains, but also to get a mutual understanding of not only the game but also each other's domains and how they can contribute to the game development process.

However, bringing experts together from different domains might also be problematic. B argues that the *exchange* of knowledge across domains can be difficult as actors from a certain domain might not be able to transfer or translate their knowledge to other domains. This could be subject matter experts or educators trying to apply their subject specific knowledge into a game format:

> *"Oftentimes, experts, like traditional experts in teaching a particular subject, can be as much of a liability as an asset. It just sort of depends on the extent to which that individual has the literacy that makes the jump from how that subject is traditionally taught, whether lectures or books or movies or what have you, to the game-based format" (Interview with B).*

This quote shows how bringing educators or teachers into a game development process has its pros and cons. The outcome of the collaboration between the experts is highly dependent on the extent that the actors from the domains outside the game design domain manage to "bring" their knowledge into the game domain.

A worst-case scenario could be that the game designers will not have access to experts from the subject matter expert domain. Consequently, the designers will have a difficult time figuring out how and what content that is relevant to meet the learning goals of the game. In that case, the game designers will not be aware about what areas of the subject that are interesting to include in the game but also what is important to include in the game's learning goals. One learning mentions a specific project, where his company failed in getting hold of relevant subject matter experts and had to start the design process before they had knowledge about the subject matter:

> *"That meant that the whole game got turned upside down. It is a flawed game because you start designing a game before you even know what problems to solve. That is not the optimal process" (Interview with A).*

This quote puts an emphasis on how the disciplinary domain is linked to framing the problem, i.e., the main challenge in the game as starting point for the learning game development.

The presented perspectives in this theme underline the importance of involving actors from both the pedagogical, disciplinary, and game design domain. All the informants agree on this matter and stress that all domains can contribute with valuable knowledge throughout the whole game development process. At the same time, there may also be highly problematic and challenging areas of collaborating across domains as all actors might not have a common understanding of how much and to what extent they can contribute to the design process.

5.2 Theme 2: Combining game elements and learning elements is key

The access to and understanding of specific learning content plays a significant role when developing learning games. Patterns across the coded data show that the learning game designers all assign the learning content and learning objectives an important role in the development process. However, acknowledging the importance of learning content alone does not make a learning game. Rather, it is essential to combine the learning elements with game elements when designing learning games. There must be a meaningful connection between what players do and experience in a game and what they are supposed to learn.

As an example, A explains that it is very important that the learning goals and the goals for the game overlap, so the game play and the learning are not decoupled. On top of that he uses the term exogenous design, cf. Squire (2006), to explain that learning game design must focus on connecting the learning content to the game contexts in which the player participates in. B confirms this statement by saying that when going into a design process the company always asks themselves:

> *"What are the learning objectives and then what are the game play mechanics that's going to serve those objectives? (...) so that it is by mastering the game [that] the players master those objectives" (Interview with B).*

Thus, B points to the relation between the disciplinary domain (learning objectives) and the game domain (game mechanics), but also indirectly to the pedagogic domain (by mastering the game process you master the objectives) meaning that the game mechanics are integrated with the learning approach.

As explained in the previous theme, actors from the game design domain are highly reliant on actors from the disciplinary and pedagogical domain being able to contribute with relevant subject matter knowledge and pedagogical knowledge to the design process. But the collaborations between the three domains can be challenging:

> *"...one of the challenges is like teasing apart their expertise ... whether it's a faculty or an educator or a subject matter expert in the field, or a researcher teasing apart their expertise on the domain and how to teach the domain, using things other than games, and then translating that in the best way possible into an interactive digital experience. And it's as much about figuring out what to discard as it is about what to be influenced by" (Interview with B).*

In this way, the content subject matter experts and educators must contribute with the most important knowledge, but the collaboration between actors from the different domains also includes discussions around what knowledge to keep and what to discard. E has faced similar challenges when working together with historians when designing a game about WW2:

> *"For them [the subject matter experts], everything needs to be in the game (...) So, I think the most pain that we have in that process is that we need to eliminate, eliminate, eliminate, and eliminate, because it is not about historical correctness. It's about the experience of the child." (Interview with E)*

In this quote we get a sense of how complicated the process of both collaboration between domains can be, but also how difficult it can be to select the specific subject matter knowledge that will add value to the game experience, which itself lies within the pedagogical domain in the context of learning.

Like E, B also have had challenging experiences when working with subject matter experts. When researching and developing a biology game for children, the game developers collaborated with scientists. This resulted in discussions about the level of detail in the learning content of the game:

> *"... it was very important to him [the scientist] ... how what we displayed in the game was exactly how it worked in the real world, which, you know, if you're overzealous about that, you can blow your entire budget on fidelity that doesn't actually contribute in any meaningful way to the learning objectives. So, there was a lot of give and take in that process" (Interview with B).*

This example shows how game designers and the scientist needed to collaborate across domains and agree upon what subject matter knowledge is important to include in the game.

When developing learning games not only the game design, but also the learning content and the learning objectives must play an important role. Other than that, the focus must be on how to integrate and connect the subject matter knowledge into the game context and the game mechanics. The theme also highlighted that the collaboration across domains can be challenging when deciding what and how much of the subject matter knowledge to include in the game. They had to find the pedagogical domain as the potential middle ground between subject matter and the game domain.

5.3 Theme 3: The school as context for learning games

The context is an inextricable part of all educational games. Across interviews, informants describe the school context and the teacher as something that weighs in on the development of learning games played in K-12 educational contexts. This highlights the pedagogical domain as an important part of the design process.

The pedagogical domain is not only something to consider and involve at the end of the process but must be given a place from the get-go. Especially E stresses the importance of including the context early in the design process:

> *"I would say that 60% of the success of your serious game is the context in which it's played. So, it's even more important than the game that we design ... And this is something that we try to get our clients involved in as soon as possible" (Interview with E).*

E clearly considers the context to be crucial for the learning outcome and that the context is even more important than the games itself. This argument is confirmed by an utterance by A that describes how his view on the context has changed from seeing the game as an isolated artefact detached from the context to now

considering the context even more important than the game itself. This is supported by B that explains how he views the context when designing learning games:

> *"Context definitely weighs heavily into the early design decisions, and everything is bespoke, right? So, it's all: What's the best design for the envisioned context in which the user is using the game and who is that envisioned user and what are their needs" (Interview with B).*

Like the other informants B also gives the context a prominent place in the development process which again underlines the importance of including actors from the pedagogical domain early on in your development process. Regarding this specific domain, you cannot get around the teacher and her role in using games in the classroom. When using games in a K-12 educational context the teacher plays an essential part of facilitating and guiding the students' use of the game.

> *"Well, the fact that you have a class with a facilitator is a God-given opportunity to create unique and game and educational experiences" (Interview with A).*

But giving the teacher such an important role also challenges the development process and the actual design of the learning game:

> *"[Y]ou have to understand as a designer that the teacher in front of the class is vulnerable in a way. She's exposed. And this means that the interaction of the application that you are creating should be so clear that no mistakes can be made." (Interview with E)*

Furthermore, using games in the classroom is a lot different from using traditional teaching materials like books. Therefore, using especially digital games in the classroom can potentially be a dangerous experiment for teachers:

> *"[U]sing a game in the classroom is ... a very dangerous experiment because many things can go wrong. Technology can fail, kids can become way too enthusiastic so that takes you at least two hours to get them focused again. So, there are so many aspects that make it for the teachers a high-risk experiment, so that even if they sort of, fakely like to do it, then they rather just pick a book and read to the group because there is no risk in that. So that makes it a harsh environment" (Interview with E).*

Here, E sees the risk of using educational games when teaching. A risk that teachers must consider taking. Again, that stresses that the teacher's role must be taken seriously in the development and design process, because using games in teaching requires different and other competences from the teacher than traditional teaching materials do.

The way the informants describe the context and the teacher's role shows us that the pedagogical domain is highly important when designing learning games. Developing games for a school context is not only about designing a fun, challenging and visually appealing game, but knowing that the context affects both the development and the actual usage of the game directly. Furthermore, the above underline the significant role that the teacher's plays when using learning games in the classroom. Therefore, teachers and their professional practice must be taken into consideration in the design process.

6. Discussion

According to Baumgartner and Bell (2001), it is crucial that educational researchers can articulate and work with specific *design principles* to guide their design experiments and development of educational technology. Similarly, we wish to argue that the findings from the three analytical themes in the analysis can be used to articulate three generic design principles, which may inform learning game designers when scoping, researching, conceptualising, and developing learning games. The first design principle relates to the need for collaborating across different domains and may be phrased as *the importance of creating a shared language and repertoire for the involved actors (e.g., game designers, subject matter experts, and educational practitioners) across different domains*. The second principle, which builds on findings from the next analytic theme, concerns *the need for establishing meaningful links between educational aims and game elements*. Finally, the third design principle concerns the importance of *considering the educational context of the learning game as a key aspect of the design process*.

6.1 Limitations of the study

There are important limitations to the study. First and foremost, the data reported in this paper is solely based on interviews. The interviews were conducted during a COVID-19 lock-down period, which made it impossible to make observations of the informants' daily work routines, development process and workplaces. Therefore, the data only builds on the informants' own reflections, descriptions, and recollections of their professional design practices. That makes it impossible to get a full overview of the design process and the context they refer to in the interviews, which then only shows us how the informants reflect on the knowledge they use when developing learning games. Moreover, we cannot tell if there are important discrepancies between what the learning game designers say and what they do (Brinkmann, 2013).

Secondly, there may be an issue with biases in the interviews. One example of this is that one of the authors of this paper has a close relationship with informant A as she has been working at A's company since 2020 and had therefore been a part of the learning game development field for over one year when conducting the interviews. This has given the specific co-author a dual role, as she was both a researcher and a participant in the field that she was researching. All informants were informed about this dual role of the interviewer before conducting the interviews. However, it is difficult to say, if informants would have responded otherwise, if the interviewer had not been affiliated with a learning game developer.

7. Conclusion

In this paper, we have analysed how five different learning game designers experience and reflect key aspects of their daily design practices when trying to design learning games for K-12 educational contexts. The study finds that learning game design is a highly complex and challenging process, which requires close interplay of different types of knowledge across different domains (game design, pedagogy, and disciplinary knowledge) to create a shared understanding of the game to be designed. We found that it is especially important to create meaningful links between learning goals and game mechanics as well as ensuring relevance of the game design to the pedagogical context in which the game is used. In our future work, we would like to further elaborate and validate design principles, which address these aspects.

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Can We Detect Non-playable Characters' Personalities Using Machine and Deep Learning Approaches?

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Abstract: Personality recognition and computational psychometrics data have become prevalent in personnel selection processes. Such assessment tools are adequate for human resources seeking tools to assess a large volume of diverse player personalities in the current "war of talents." Recently, studies about using Gamified situational judgment test approaches have shown positive results in assessing players' behavior and personality. Gamified situational judgment tests combine the advantages of gamification, such as enhancing players' reactions and flow state, with the acknowledged traditional situational judgment test approach. To gamify a situational judgment test, an innovative approach using the visual novel game genre has shown positive results in the gamification by adding game elements such as narrative scripts, non-player characters, dialogs, and audiovisual assets to the test. Indeed, these elements play an essential role in the validity of the players' personality results by using a stealth-assessment method to minimize social bias and player's stress. However, to our knowledge, as gamification in personality detection is still recent, little is known on the possible positive outcomes of designing game elements such as the dialogues and non-player character personalities in the validity of the team cohesion measure. To this end, we propose an empirical study to build personality trait models based on non-players characters' speeches. We used the Myers–Briggs Type Indicator based on four dichotomies to classify the personalities as one of companies and organizations' most used personality typology. For each of the four dimensions, we train twenty-four separate binary classifiers and one 16-class classifier, using well-established machine learning and a convolutional neural network in the domain of natural language processing, text analytics, and computational psychometrics. The results of this study show that it is possible to recognize non-playable characters' personalities and thus can help game designers to understand their characters' personalities using natural language processing.

Keywords: Natural Language Processing, Personality Recognition, Machine Learning, Visual Novel Game.

1. Introduction

Human resources (HR) and companies have shown a growing interest in applying game-based approaches (GBA) in personnel training, recruitment, and selection. Serious games, gamification, simulation, and learning games are a non-exhaustive list of GBA already well-established for training purposes (De Freitas, 2018). However, GBA selection processes have just risen (Bina, Mullins and Petter, 2021). They tend to encourage the right people to candidates and enable the people's hard and soft skills assessment to fit the right person with the right corporate team. Consequently, companies and HR departments are researching and developing reliable and valid gamified tools such as serious games or gamified procedures to enhance recruitment processes (Armstrong, Landers and Collmus, 2016).

Bina, Mullins and Petter (2021) reveal in their literature review, which examines game-based approaches in HR recruitment and selection, that for a decade, the industry field and companies created games to attract candidates and enhance applicant reaction towards the company attractiveness (Georgiou, Gouras and Nikolaou, 2019). In addition, technology-driven solutions enhance the effectiveness of gamified tools for assessment, and personnel selection (Woods *et al.*, 2020). Indeed, the new generations are used to play games on different platforms such as mobile, tablets, computers, and virtual headsets. Moreover, with the advancement and the simplification of video game engines such as RPG Maker, Unity 3D, or Unreal Engine, creating and providing digital games and gamified tools for human resources purposes is more accessible for companies, nowadays. However, Bina *et al*. (2021) highlighted that the academic literature is still limited regarding the development of easy-to-use tools for HR people.

Traditional soft skill and personality recognition tests are commonly based on well-known behavioral and personality models such as the Myers-Briggs type indicators (MBTI) (Myers, 1962). Such tests traditionally use situational judgment tests (SJT) approaches to assess the different soft skills or individuals' traits. In personnel

selection, SJT are used by companies because of their ease to develop and deploy. SJT are also efficient in assessing a large panel of candidates' behaviors (Motowidlo, Dunnette and Carter, 1990). Indeed, companies are currently focusing on developing tools that enable soft skills and personality detection as companies' success is highly related to employees' hard and soft skill combination (Heckman and Kautz, 2012).

Georgiou *et al*. (2019) propose the development of a digital and gamified assessment for employee selection, resulting in positive preliminary findings by combining GBA and SJT approaches. Similarly, Hernandez *et al.* (2021) propose a framework to help game designers and stakeholders to develop and deploy a gamified SJT based on the visual and interactive narrative novel game genre incorporating game elements such as audiovisual assets, graphics assets, and interacting non-playable characters. In the context of behavioral recognition and to pursue Bina *et al*.'s (2021) research agenda about studying game elements that assess social interaction as desirable candidate abilities, we propose to study the non-playable character (NPC) game element in this article. To clarify the context, the company we work with for this research (Origamix) followed the Hernandez *et al*. (2021) approach to create visual novel games that contain numerous real-life situations and non-playable characters for behavioral and team cohesion assessment purposes. Furthermore, we think in concordance with the company goals that designing non-playable characters to reflect the real future candidates' teammates may enhance the construct validity of the gamified tool in the personnel selection context where companies want to fit the right person in the right team.

For this reason, we propose in this article to generate personality text-based classifiers to categorize visual novels' non-playable characters to help game designers and writers in creating better gamified selection tools. We use natural language processing approaches and compare different machine learning and deep learning methods to classify the non-playable characters according to their speeches. Therefore, on the one hand, we support in this article that machine and deep learning enable viable NPCs' personalities recognition. On the other hand, we propose comparing and finding the best algorithms methods to generate personality traits classifiers.

The remainder of this paper is organized as follows. Section 2 presents an overview of related works using natural language processing to detect personality from text-based documents. Section 3 describes the MBTI typology used for the study and the data collection process. Section 4 presents the methodology applied to generate the different classifiers. Finally, section 5 deals with the outcomes, compares the classifiers' results and concludes with the proposition of possible future works to pursue.

2. Related work

2.1 Human-Like NPCs

Non-playable characters' personality studies have risen along with the development of digitals games at the end of the 2000s. Park and Henley (2007) revealed the importance of giving life to believable NPCs for the players based on emotional, personality, and social relations models. Early experiments in imbuing personality to NPCs were based on probabilistic approaches (Min *et al.*, 2008). For instance, Cho, Song and Um (2007) use a combination of a probabilistic state machine with a Gaussian random distribution to make NPCs make stochastic decisions in-game. However, this approach enables a character to act with randomly pre-defined actions taking into account its environment but does not imbue the NPC with a complex personality based on behaviors, cognitive abilities, and emotional patterns. In addition, such approaches are not used for dialogues generation, which is the main game element of a visual novel. For these reasons, others developed personality and emotional models and frameworks intending to imbue human-like behaviors and personalities. For example, Bosch *et al*. (2012) propose a framework based on the Belief-Desire-Intention concept (Georgeff *et al.*, 1998) to individualize NPCs with their own personality. The researchers developed a game where they model NPCs with a combination of an extrovert or introvert trait with an agreeable or non-agreeable trait to strengthen the NPCs' human-like behavior and enhance the flexibility of these latter. Furthermore, these personality dichotomies are also represented in the MBTI typology. Indeed, the MBTI's personalities result from several human behaviors and psycho-sociological studies. Hence, following such typology to shift no-social behavior NPCs into human-like characters with rich personalities and emotions enhance players' gaming experience and engagement. The latter statement is particularly true in high interactive narratives games like visual novel games. For instance, project Scheherazade (Aljammaz *et al.*, 2020) combined social simulation, natural language processing, and knowledge modeling to enhance NPC interactions, players' engagement and interest in the game.

2.2 Natural Language Processing

Deep neural networks and machine learning approaches (Goodfellow, Bengio and Courville, 2016) are currently widely applied to natural language processing (NLP) (Khan *et al.*, 2016). Aikawa, Schwartz and Pahud (2005) proposed a Story Maker tool to generate animated scenes and direct visual output to the users in response to their textual input. This study provides preliminary findings on the potential positive results in the use of NLP for creating stories. NLP tasks and applications may play an important role in enhancing the game creation processes and the players' experience (Picca, Jaccard and Eberlé, 2015). This statement is all the more relevant for visual novel games (Domsch, 2017) where textual interaction, storytelling, dialogues, and speeches are the core elements of such games (see figure 1).

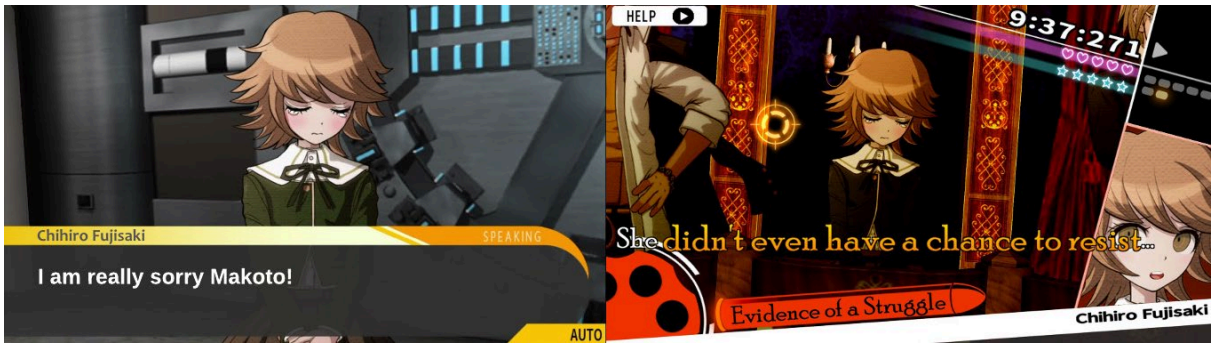


Figure 1: Screenshots of Danganronpa: Trigger Happy Havoc Visual Novel Game

2.3 Personality Detection

The company supporting this research receives inquiries to generate visual novel games to assess people's personalities using the MBTI typology. Although such model is usually used to describe real-life human personality, Ochs, Sabouret and Corruble (2009), also support the use of psycho-sociological and personality models to enhance NPC.

Research about personality recognition using NLP with a machine and deep learning approach has yielded positive results. For instance, Golbeck, Robles and Turner (2011) reveal that analyzing socials users' footprints, such as sentences or words used in social media, may become an efficient way to predict individuals' behavior and personalities. Indeed, Sönmezöz, Uğur and Diri (2020), also support and highlight that social media are rich in psychometrics data and information that enable machine learning and deep learning algorithms to predict personalities efficiently from textual documents. Following these previous works, some researchers compared different deep learning and machine learning approaches based on personalities typologies. Tripathy, Agrawal and Rath (2016) reveal in their literature review that support vector machine, decision tree, and naive Bayes algorithm are well used in sentiment analysis based on text classification. Likewise, some researchers also proposed in their projects or reviewed the random forest, linear regression, and deep learning approaches for such NLP tasks (Cui and Qi, 2017). Majumder *et al*. (2017) also highlight that deep learning and neural networks approaches are powerful means to detect personality from a text.

Many methods and approaches have already been studied using social media datasets such as the open sources Kaggle's datasets or Gjurkovic and Snajder's (2018) dataset that regroup several posts from social users and the users' personalities. However, social posts are written by one user following a monologue structure that may semantically differ from NPC dialogues and speeches. Amongst the existing research projects that study serious games to detect players' personalities and behavioral profiles (Palhano, Machado and De Almeida, 2020), to our knowledge, no research studies the use of NLP to detect NPCs' personalities. Hence, following the previous related works approaches, we propose a preliminary research on text-based classifiers to categorize NPC's personality. Accordingly, we offer the following hypothesis and research question:

Hypothesis. We can generate viable classifiers to detect non-playable characters' personalities from their dialogues following the various literature approaches on using natural language processing for personality recognition.

Research Question. Which supervised learning methods generate the best binary classifier for each personality trait among the MBTI typology?

3. Psychometry and Dataset

3.1 Myers Briggs Type Indicators

This study focuses the research on the MBTI, briefly explained in section II to measure personality traits:

- Extraversion/Introversion (E/I) dichotomy reveals how an individual interacts with his/her environment and the others.
- Intuition/Sensing (N/S) dichotomy reflects how an individual perceives the collected information from his/her surroundings.
- Feeling/Thinking (F/T) dichotomy depicts how an individual decides to act.
- Judging/Perception (J/P) dichotomy determines the attitude that influences an individual's way of living or working.

Combining the four individuals' dichotomous traits leads to 16 possible personality types. These types are represented by four letters that describe an individual personality. An individual with the Extraversion, iNtuition, Feeling, and Perception traits is an ENFP type. An ENFP individual is a free spirit who is a cheerful, communicative person, attached to his values and in search of existential harmony.

3.2 Data Collection

We created our dataset by extracting the characters' speeches (12600 speeches/dialogues) from nine famous visual novels. Figure 2 details the data collection and dataset generation processes needed to generate the classifiers.

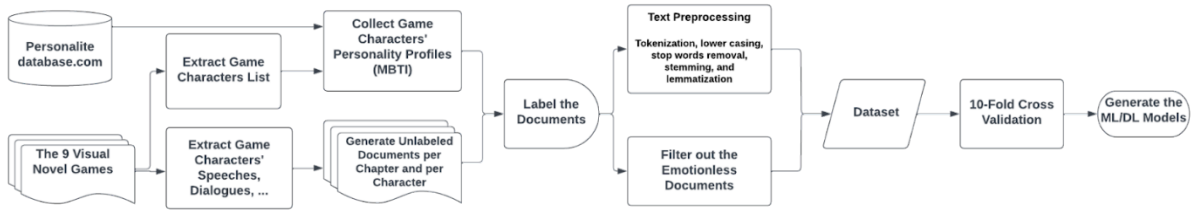


Figure 2: Data Collection and Dataset Generation Processes

In supervised machine learning, labeled data are required as input to train the model. Hence, each character must be tagged with multiple labels corresponding to the four MBTI dichotomies. The players are the most predisposed to tag the characters as they directly interact with the NPCs. Therefore, we used the *"personalitydatabase.com"* (PersonalityDatabase LTD, 2022) platform that enables players to vote for the personality of any fictional characters from numerous video games. We extracted 170 non-playable characters' personalities from the game pool and labeled each characters' speech with their corresponding personalities.

We observed that each game chapter is a particular context where the characters' personalities are displayed in a certain way connected to the chapter situation. In addition, keeping the entire dialogues and speeches of a character in a single document may confuse the training as the character may display a broad panel of emotion during the entire game. Furthermore, we also use deep learning in the study that may capture the emotional behavior of a character in a specific situation connected to its personality. In other terms, a character may display its emotions differently depending on the context and situation, with its personality as a constant.

For this reason, we proposed to regroup the speeches and dialogues into several documents that represent all the sentences used by a specific character in a specific game chapter. This process provides 6200 labeled points in the form (document, MBTI traits).

4. Methodology

This research aims to discover preliminary findings on supervised learning and natural language processing to enable non-playable character personality recognition. Following Rahman *et al*. (2019), and Majumder *et al*. (2017) approaches, splitting and studying the personality traits independently analysis results in better outputs than studying the combination of the traits as a single type. Therefore, we proposed to compare various character speech-based binary classifiers for each of the four MBTI dichotomies. We also use deep learning algorithms to generate and compare a 16-class classifier.

We use the dialogues/speeches and the characters' psycho-metrics as the data entry points to train the models. The process of training classifiers in natural language processing is globally divided into three steps:

- Dataset Analysis
- Data Preprocessing
- Model Training

The following subsections of this section explain the details of those steps.

4.1 Dataset Analysis

We performed a preliminary analysis of the MBTI's types distribution and the various personality traits distribution independently to ensure we can use the collected dataset. Figure 3 reveals that the dataset is not uniformly distributed among the sixteen personalities depicted by the MBTI typology. For example, the least frequent personality among the data points is INFJ with 35 occurrences, whereas the most frequent personality is ISFJ with 936 occurrences.

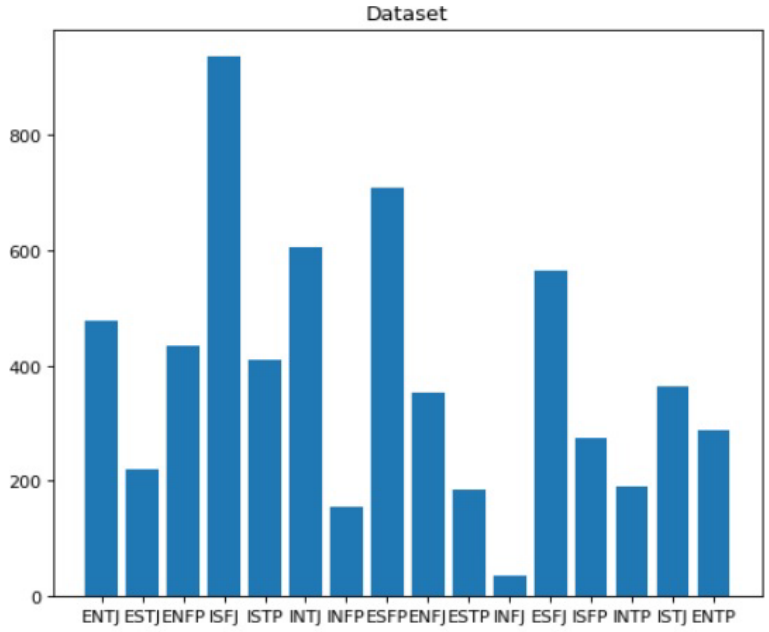


Figure 3. MBTI Dataset Distribution Analysis

Nevertheless, the study aims to compare binary classifiers for each personality trait following Majumder *et al*. (2017) methodology. Hence, Table 1 reveals that the data are better distributed among the four MBTI dichotomies independently of one another. The difference between the two possible labels in a specific trait is too slight to consider a remediation method such as class duplication or reduction (Cui and Qi, 2017). As a result, we are training on the original dataset with 6200 data points for the MBTI dataset.

Table 1: MBTI's Traits Distribution

MBTI Personality Trait	Occurrences
E / I	3231 / 2969
S / N	3663 / 2537
T / F	2736 / 3464
J / P	3556 / 2644

4.2 Data Preprocessing

To train our models efficiently, emotionless characters' documents that do not carry any personality cues are filtered out of the dataset to avoid noise in the model training. Afterward, we apply standard text preprocessing steps such as tokenization, lower casing, stop words removal, stemming, and lemmatization to enhance the training process.

4.3 Model Training

The MBTI typology suggests that collecting the four traits defines a character or an individual's personality. In section III, we highlighted that each personality traits were dichotomous. In other words, each personality trait contains only two possible categories to which an individual or a character may belong. Hence, we generate classification models that enable a character's category identification for each personality trait. For this reason, we propose to compare several supervised learning approaches that generate binary classifiers. We use five machine learning algorithms for text classification and one convolutional neural network to generate the various classifiers for each personality trait and the 16-class classifier.

4.4 Supervised Machine Learning Algorithms

The academic literature reveals that logistic regression algorithms (LR), support vector machine algorithm (SVM), decision tree algorithms (DT), Naive Bayes Algorithm (NB), and random forest algorithms (RF) are well-established and effective supervised machine learning for natural language processing and text-classification (Khan *et al.*, 2020). We use a bag-of-word algorithm to generate our vector representations for words by considering each word count in a document as a feature. Finally, we perform 10-fold cross-validations for each personality trait and for each supervised machine learning algorithm to obtain the models' accuracy and F1-Score (see table 2).

Table 2: Supervised Machine Learning Classifiers Evaluation and Comparison

	Logistic Regression		**Support Vector Machine**		**Naive Bayes**		**Decision Tree**		**Random Forest**	
MBTI Traits	**Accuracy**	**F1-Score**	**Accuracy**	**F1-Score**	**Accuracy**	**F1-Score**	**Accuracy**	**F1-Score**	**Accuracy**	**F1-Score**
E/I	.714	**.718**	.691	.696	.613	.551	.626	.638	.687	.697
S/N	.710	**.613**	.689	.599	.682	.542	.615	.519	.681	.502
T/F	.719	**.755**	.689	.728	.663	.732	.604	.649	.694	.751
J/P	.717	.764	.686	.731	.666	.745	.618	.671	.714	**.784**
Overall	.261	**.254**	.225	.222	.185	.163	.144	.144	.232	.206
Average	.715	**.713**	.689	.689	.656	.643	.616	.619	.694	.684

4.5 Deep Learning Algorithm Using Convolutional Neural Network

A convolutional neural network (CNN) is a kind of neural network that includes convolutional layers that enable classifying text-based documents. Figure 4 roughly explains the following Zhang and Wallace (2015) classification approach using a CNN for NLP tasks such as binary classifying documents or sentences. First, an embedding process is applied to represent the text using vectors. Afterward, the documents or sentences are encoded into matrices taking account of the document context and using the CNN architecture. Then, a prediction phase enables to infer the classification using a multi-layer perceptron.

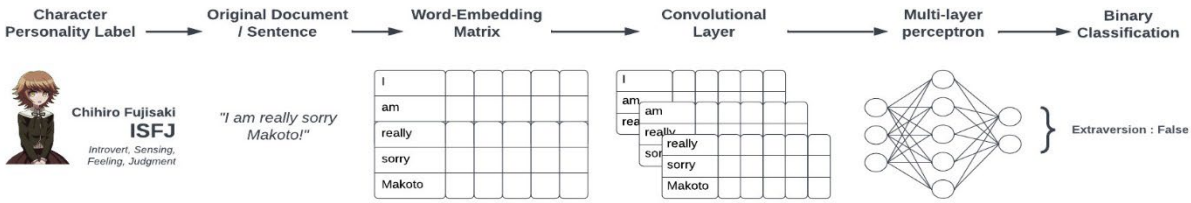


Figure 4: Classification process using CNN approach with spaCy library

CNN enables the training of a multi-class classifier for the sixteen MBTI personality types. In addition to the personality traits binary classifier training, we train a 16-class classifier to analyze whether a deep network could obtain better results than our binary classifiers. The results show an accuracy value of 0.728 and an F1-Score value of 0.715 for the 16-class classifier. Alternatively, Table 3 shows our best results for the binary classifiers after tuning multiple parameters and randomly training the CNN several times.

Table 3: Convolutional Neural Network Classifiers Evaluation

MBTI Traits	**Accuracy**	**F1-Score**
E/I	.721	.707
S/N	.704	.638
T/F	.721	.684

MBTI Traits	Accuracy	F1-Score
J/P	.734	.775
Overall	.269	.239
Average	.720	.701

5. Results and Discussion

5.1 Supervised Learning Methods Comparison

Table 4 reveals our best-performing models for the MBTI typology with O.Acc, O.F1, A.Acc, and A.F1 representing the overall accuracy, the overall F1-score, the average accuracy, and the average F1-score respectively.

Table 4: Methods Comparison for the MBTI Typology

Model Type	O.Acc	O.F1	A.ACC	A.F1
Logistic Regression	.261	.254	.715	**.713**
Support Vector Machine	.225	.222	.689	.689
Naive Bayes	.185	.163	.656	.643
Decision Tree	.144	.144	.616	.619
Random Forest	.232	.206	.694	.684
Binary CNN	.269	.239	**.720**	.701
16-Class CNN	**.728**	**.715**		

The results highlight that the 16-Class classifier generated by the CNN approach for the MBTI typology outperformed the overall results of the binary classifiers. In other terms, the 16-Class CNN model is the one to use if we are looking to classify documents following MBTI's personality types. However, game stakeholders and writers may be more interested in recognizing a sole personality trait than the MBTI types. Although the overall accuracy and F1-score are not jaw-droppingly high, the average accuracy and F1-score reveal better results in classifying the MBTI's dichotomies.

These results are constant with the scientific literature that conducted their studies using the social media posts or the different personality Kaggle datasets. According to our hypothesis question, our models show positive preliminary results in predicting NPCs' personalities based on their dialogues and speeches. In addition, three of the six supervised learning approaches performed better F1-Score results considering table 5 which compared the top classifiers by traits. Answering our research question, the logistic regression, the random forest, and the convolutional neural network are the top three approaches to classify characters' personality dichotomies among the MBTI. However, the models may need to be trained again or use transfer learning techniques to be accurate with new NPCs who are not present in the current dataset (Weiss et al., 2016).

Table 5: Top classifiers by traits

MBTI Traits	Model Type	Accuracy	F1-Score
E/I	LR	.714	**.718**
S/N	CNN	.704	**.638**
T/F	LR	.719	**.755**
J/P	RF	.714	**.784**

5.2 Limits of the study

Although the positive results emit evidence of using machine learning and deep learning approaches to detect NPCs' personalities, future research projects have to consider some limitations.

First, a range value of 0.146 between the best F1-scores in Table 5 reveals that classifiers are not equal in performance to detect personality traits among the different traits. This difference may be explained by the difference in the distribution for the dichotomies as seen in subsection 4.1. Likewise, personality indicators such as emotions present in characters' dialogs may differ in quantity. In other words, some personality traits may be more complex to analyze with NLP than others.

Second, we performed our various training with a dataset with approximately the same amount of entry as the datasets used in the academic literature. However, a more extensive and enriched dataset may result in better and more accurate outcomes to enhance the generated classifiers' reliability and validity.

Third, the current results lack neutrality as the documents from the test dataset may be related to some documents from the training dataset. The documents are unique and cannot be present in both training and test sets simultaneously. Nevertheless, they may be semantically similar as they come from the same non-playable character. Indeed, to create our entire dataset, we split characters' entire game speeches and dialogues into several documents.

Finally, as a preliminary study, we did not focus the study on tuning in the best way the different parameters or hyper-parameters of the supervised learning algorithms even though such processes may result in better classifiers' performances (Majumder *et al.*, 2017).

6. Conclusion

The present study has demonstrated preliminary findings on the viability of using machines and deep learning to detect non-playable characters' personalities from visual novel games. We train multiple binary classifiers and one 16-class classifier using a natural language processing approach based on the characters' speeches and personalities. We further proposed the best model among the generated ones for each trait among the MBTI typology. Nevertheless, a difference of 0.094 among the binary classifiers' average F1-Scores reveals that there is no significant difference among the binary classifiers' results. To clarify, any traditional supervised learning methods enable personality recognition through natural language processing.

Besides, MBTI typology is one of the most used in the industry but its validity is academically criticized. Therefore, we proposed to focus the study on the binary classifiers' training for the typology dichotomies. Indeed, each dichotomy may represent two independent soft skills that may be valued in a recruiting serious game. Although the generated models are viable in visual novel character personality prediction, further studies based on different typologies and with multiple extensive data sets are needed to overcome this study's limitations.

Furthermore, the question that arises from this research is how to use the generated models in our specific context. Our specific context asks us to develop a tool to help the sponsor company's visual novel writers. In a first use case, we used the models on two learning visual novel games that we created prior to this study. According to the result, we amended some dialogues in order to make the characters' personalities more accurate. In the same way, the company's writers may use our models to check the consistency between their characters' dialogues and the stakeholders' objectives to reflect the characters' personalities with their team employees' personalities.

However, natural language processing may also be used differently to enhance visual novel creation processes and gameplay. Reflections about text suggestions for writers and auto-generation dialogues from players' interaction are under consideration to pursue this study taking into account the sponsor company objectives.

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Refurbishing the Educational Escape Room for Programming: Lowering the Threshold and Raising the Ceiling

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Abstract: Programming education at university level has often been identified as problematic learning. At the same time, prognosis for future labour market is increased need for professionals with programming and related skills. To meet demands of future society, K-12 schools around the world have integrated programming in the curriculum. However, research show challenges for integrating programming in K-12 education. Challenges include students' and teachers' struggle with learning and teaching programming, lack of time to properly incorporate programming in existing teaching and learning, and insufficient support for teachers. This study addresses these challenges by designing, developing, and evaluating an educational game on programming that combines the idea of game-based learning with digital escape rooms. In the game, the player develops knowledge about programming concepts to escape 10 rooms. The study's main research question was: What are K-12 students' perceptions of the game and what do they considered to be important design factors for a digital escape room game on computer programming? A design science approach was used for designing, developing, and evaluating a web-based escape room game on programming. This was conducted in a five-step process: 1) Explicating the problem, 2) Defining the requirements, 3) Designing and developing the artefact, 4) Demonstrating the artefact, and 5) Evaluating the artefact. The game was tested and evaluated by 32 K-12 students with a questionnaire during the autumn semester of 2021 and spring semester of 2022. Collected data were then analysed and grouped into categories to answer the study's aim and research question. Findings of the study show several suggestions for further development and important design factors to consider when developing a digital escape room game. The next steps of research are to combine these findings with evaluations from teachers, and to incorporate this in an updated version of the game.

Keywords: Escape rooms, Game development, Game-based learning, Programming education, K-12 education

1. Introduction

Computer programming has been addressed in previous research as problematic learning, regarding student drop-out and satisfaction in higher education (Pereira et al., 2019; Marcolino & Barbosa, 2017; Gomes & Mendes, 2007). At the same time, research highlights the need of professionals with STEM (Science, Technology, Engineering and Mathematics) and 21st century skills on future labour market, in which programming is an important part (Tikva & Tambouris, 2021; Admiraal et al., 2019). To meet the demands of future labour market and society, a global trend has been to integrate programming in kindergarten to grade 12 (K-12) education (Tikva & Tambouris, 2021; Szabo et al., 2019). In Sweden, the integration of programming in K-12 curriculum was decided and outlined by the Swedish government in 2017 (Nouri et al., 2020; Heintz et al., 2017).

However, research show challenges for teaching and integrating programming also at K-12 level. In the UK, computing education has been described as "patchy and fragile" with lack of teacher support (The Royal Society, 2017). Research have further described a lack of time for the integration and challenges for both teachers and students to learn programming (Allison, 2021; Humble, Mozelius & Sällvin, 2020). To address the challenges of integrating programming in K-12 education, this study describes the process of designing, developing, and evaluating an educational game on programming. The game design combines the idea of game-based learning (Hussein et al., 2019) with that of digital escape rooms (Veldkamp et al., 2020) to foster student understanding of basic concepts within computer programming.

With the design science idea of iterative development this study could be seen as the second iteration of the game development presented by Humble, Mozelius & Sällvin (2021). Striving for a more inclusive game design, authors have had the ambition of lowering the threshold and raising the ceiling of educational escape rooms on programming. That is, getting more students interested in programming through educational escape rooms (lowering the threshold) while still facilitate learning and engagement in programming (raising the ceiling). The aim of the study was to design, develop and evaluate a digital escape room game on computer programming for K-12 students, with the main research question: What are K-12 students' perceptions of the game and what do they considered to be important design factors for a digital escape room game on computer programming?

2. Extended background

Computer programming has been identified as a subject that many students find challenging and problematic to learn (Chetty & Barlow-Jones, 2012; Hawi, 2014; Malliarakis, Shabalina & Mozelius, 2021). An ongoing reform that will facilitate programming education at university level is the introduction of programming in K-12 education. At the same time, challenges associated with introductory programming will be shifted to the younger audience, with an even more urgent need for pedagogy shift and curriculum development (Lédeczi et al., 2021). This paper suggests combining the old tradition of game-based learning with the current trend of educational escape rooms.

2.1 Game-based learning

The tradition of using games and play in educational contexts is far older than using computers. Various types of games have for thousands of years been used for training in areas such as mathematics, logics, and combinatorics (Vankúš, 2005; Hellerstedt & Mozelius, 2019). Areas that all are useful in the process of developing fundamental programming skills and for the general understanding of computer science. In computer science, the construction and analysis of games have resulted in creation of valuable knowledge. Two prominent computer scientists that have been pioneers in this field are the chess aficionados and creative game developers Alan Turing (1953) and Ken Thompson (1986). In programming, educational games have been involved in teaching and learning activities both for learning by creating games (Seralidou & Douligeris, 2021), and for learning to program by playing games (Miljanovic & Bradbury, 2018). This could also be carried out for the younger audiences (Gomes, Falcão & Tedesco, 2018), with the use of open educational games (Silva & Silveira, 2020). A related concept is that of flow and the flow channel, which is the state between anxiety and boredom where the player experience peaked enjoyment and focus (Csikszentmihalyi, 1975; Neal, 2012).

2.2 Educational escape rooms

The much younger trend of Escape rooms started out as leisure gaming, and often with the purpose of team building. With the aim of keeping the fun, the escape room concept has also been reused for different educational purposes such as chemistry (Yayon et al., 2019) and language learning (Urbieta & Peñalver, 2019). What inspired this study was that escape rooms have showed promising learning support in the domains of science, technology, engineering, and mathematics (STEM), and the computer science domain (Borrego et al., 2017). The STEM disciplines have acted as pioneers in the construction and use of educational escape rooms, with a frequent use of escape rooms in teaching and learning activities (Veldkamp et al., 2020). Finally, and even more inspiring, the escape room concept has also been tested with promising results in programming courses (López-Pernas et al, 2019), both for face-to-face activities and in distance mode (López-Pernas et al, 2021).

3. Method

Hevner et al. (2004) describe design science as “a problem-solving paradigm” that seeks to innovate ideas, practices, and technical artefacts. A common goal of design science is to produce design knowledge, that is, knowledge that support problem-solving in the design of solutions (Engström et al., 2020). A design science approach, inspired by Johannesson and Perjons (2014), was used to structure this study in five steps:

1. Explicate the problem
2. Define requirements
3. Design and develop artefact
4. Demonstrate artefact
5. Evaluate artefact

The first step, to explicate the problem, is addressed in the sections *1. Introduction* and *2. Extended background* of this study. The problem was also identified through discussions in professional development courses on fundamental programming for K-12 teachers, where the authors worked as course facilitators (Humble, Mozelius & Sällvin, 2021). In the second step, the requirements for the learning outcomes of the game were designed to closely align with the syllabus framework for the previously mentioned teacher professional development courses. The syllabus framework is recommended by the Swedish National Agency for Education and address what programming skills K-12 teachers in mathematics and technology should learn, and later use with their students.

In the third step, the game was designed and developed with the game development tool RPG Playground (RPGPlayground.com) where web-based role-playing games (RPGs) can be created and shared on the website.

Since the game is web-based it can be played on both computers and mobile devices. The game is built on the idea of educational escape rooms to facilitate motivation and learning through problem-solving (Hacke, 2019; López-Pernas et al., 2019). The aim of the game is to escape 10 rooms through problem-solving, where each room address a specific programming concept from the syllabus framework. In total, 5 programming concepts are addressed throughout the game. The first time in an easier challenge and the second time in a more difficult challenge (Table 1).

Table 1. Summary of content in *Escape with Python*-game

Room	Programming concept
01	Variables
02	Variables
03	Sequences
04	Sequences
05	Conditions
06	Conditions
07	Iterations
08	Iterations
09	Functions
10	Functions

The game has shorter dialogues with non-playable characters (NPCs) to learn programming concepts, the players' knowledge is tested by trying to escape a room where that knowledge is required. In both the dialogues and challenges, metaphors and real Python-code are used to exemplify the programming concepts. The working title of the game is *Escape with Python* (Figure 1). Step 4 (demonstrate artefact) and step 5 (evaluate artefact) are addressed in the subsections: *3.1 Data collection* and *3.2 Data analysis*.

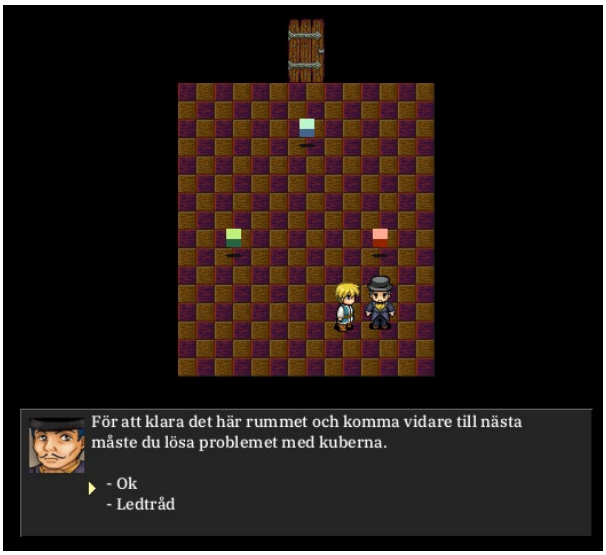


Figure 1. Screenshot from *Escape with Python* (By Niklas Humble in RPGPlayground.com)

3.1 Data collection

The game was demonstrated and evaluated by 32 students in K-12 education during the autumn semester of 2021 and spring semester of 2022. Data were collected through a questionnaire with a combination of Closed-ended and Open-ended questions to collect comments, feedback, and suggestions on the perception of playing the game, and how to improve it (Farrell, 2016; Hancock, Ockleford & Windridge, 2001). The collection process started with an open invitation for K-12 students to test and evaluate the game in a professional development course on programming for K-12 teachers in the autumn semester of 2021.

4 teachers answered the call and expressed interest in testing and evaluating the game with their students. The questionnaire was sent to the teachers, together with information about the study and an agreement form, to be distributed among students. 2 of the teachers were able to complete the test and evaluation of the game with their students and re-sent the questionnaires and agreement forms. The game was used as part of an

introduction to programming by one teacher, and together with students that had showed interest in programming by the other teacher.

In total 32 students tested and evaluated the game. 28 students in grade 9, 2 students in grade 8, 1 student in grade 7, and 1 student did not specify grade. The gender distribution of the students were 18 boys, 11 girls, and 3 did not specify gender. The most common context for testing and evaluating the game was during a lesson in technology (23), followed by mathematics (4) and programming (3). Students attend K-12 schools in the mid and north part of Sweden.

3.2 Data analysis

Answers to the Closed-ended questions were analysed in a spreadsheet document to calculate the average value of each question and the number of students that reported an increase or decrease in knowledge and interest development in programming by playing the game. In total there were 4 Closed-ended questions on perceived knowledge and interest in programming before and after playing the game. In each question, students were asked to grade their knowledge/interest in programming on a scale from 1 to 10 before and after playing the game.

Answers to the Open-ended questions were analysed in a thematic analysis to identify themes and group these into categories that answer the study's aim and research question (Clarke, Braun & Hayfield, 2015). A spreadsheet document was used, and themes were grouped into subcategories under each Open-ended question. The subcategories were then reorganised in the categories: Design factors for game graphics, Design factors for game mechanics, Design factors for game content, Design factors for learning and engagement. In total, there were 7 Open-ended questions on the perception of the game. Questions addressed the following topics: 1) look and graphics of the game, 2) interaction and mechanics of the game, 3) content and challenge of the game, 4) knowledge development of the game, 5) interest development of the game, 6) engagement of the game, and 7) other opinions and suggestions for improvements.

4. Results and analysis

Average value of Closed-ended questions showed no significant change in perceived knowledge or interest development in programming by playing the game. The average answered values of knowledge and interest in programming are about 4.6 both before and after playing the game (Table 2).

Table 2. Average value on a 1-10 scale for Closed-ended question

Question	**Average value on 1-10 scale (rounded for 2 decimals)**
How would you value your knowledge in programming before playing the game (where 1 is very low and 10 is very high)?	4.48 (31 answers)
How would you value your knowledge in programming after playing the game (where 1 is very low and 10 is very high)?	4.64 (31 answers)
How would you value your interest in programming before playing the game (where 1 is very low and 10 is very high)?	4.77 (30 answers)
How would you value your interest in programming after playing the game (where 1 is very low and 10 is very high)?	4.58 (31 answers)

However, analysing for increase and decrease of knowledge and interest in programming by playing the game, results are different (Table 3). 12 students valued that their knowledge in programming had increased by playing the game, while 5 students valued that their knowledge had decreased by playing the game, 14 students valued that their knowledge stayed the same by playing the game, and 1 student did not answer both questions. Regarding interest in programming, 7 students valued that their interests had increased by playing the game, while 6 students valued that their interest had decreased by playing the game, 17 students valued that their interest stayed the same by playing the game, and 2 students did not answer both questions.

Table 3. Perceived knowledge/interest development by playing the game

Knowledge / Interest	Increase	Decrease	Same
Perceived knowledge development by playing the game	12	5	14
Perceived interest development by playing the game	7	6	17

The Open-ended questions provide more detailed answers on the perceptions of the game and suggestions for improvements. Results of the thematic analysis are presented in sub-headings below.

4.1 Design factors for game graphics

Results of the open-ended questions show that students liked the retro-feel of the game and that it looked familiar to other games that they play. On the more critical side, some students suggested that there could be improvements to the overall design of the game. More details in the rooms, better graphics, background music, and voice acting were suggested. On the other side, some student appreciated the minimal design of the game and expressed that they liked that they could see what they were doing in the game. It was also suggested that player customisation should be added to the game, which would allow players to take control over how they were visually represented in the game (Quote 1).

> *"Good, the design was simple and you did not get overwhelmed. But you should be able to do customisation on the character that you play and design its' look. Or, if there were other worlds that you could travel to."*

Quote 1. Student about graphical design and customisation of the game.

4.2 Design factors for game mechanics

The results further show that students perceived the gameplay as unclear or inconsequent throughout the game. For example, that an approach used for problem-solving in one room did not reoccur in the next (Quote 2). On the other hand, some students perceived that the game was easy to play and understand. Students also suggested that more freedom should be added to the gameplay. For example, players should be allowed to explore the game environment more freely and be able to write real code in the game, instead of selecting pre-written code. It was also expressed that dialogues with NPCs were appreciated but presented too slow.

> *"In some rooms you used those glowing things to do stuff but in other rooms you walked up to some character to do stuff. It feels a bit inconsistent."*

Quote 2. Student about gameplay and mechanics of the game.

4.3 Design factors for game content

Regarding content of the game, results show that some students perceived it to be too difficult while others perceived it to be too easy. This seems to relate to students' prior experience of programming, which were varied. Results further show that the presentation of code and instructions in the game's dialogues could be improved. There were too many dialogues to read, and code was difficult to understand when presented in a dialogue. Students also perceived that it was difficult to remember everything they needed to solve the problems in the rooms. Students further suggested that more excitement could be added to the game by applying a "life-system", which would determine the numbers of chances that players would get to solve a problem (Quote 3). This would also address the problem pointed out by students that it was possible to "cheat" or guess your way through the game, since there were no repercussions for wrong answers or choices.

> *"I think that the game should have some sort of life-system. Because you can test all the answers without consequences. You don't really have to think to finish the game."*

Quote 3. Student about the content and challenge of the game.

4.4 Design factors for learning and engagement

Students expressed that they found the game engaging and that they learned when game content related to school content or when the game was perceived as usable. Students expressed that they learned loops, being iterative, being accurate, and wanting to learn more about programming and creating their own games. Some students expressed that they perceive programming to be difficult and require too much work. This could be addressed with more in-game explanations and hints, which was also highlighted in the comments. Lastly, the results show a comparison between learning games and leisure games. Some students expressed that they were

not interested in programming or a game about programming, that it was not fun, or should be about something else than programming (Quote 4). Some students expressed that they liked the game, found it to be fun (for a learning game) but that they would not play it outside school.

> *"To some degree the game was fun. But I think it was very much the same over and over again. Maybe it should be about something else than programming. For example, about going on an adventure."*

Quote 4. Student about engagement in the game.

5. Discussion

A potential problem for the study's results were identified in the analysis of the closed-ended questions. Students that expressed a more critical or negative view of the game often reported a larger decrease in knowledge and interest in programming after playing the game. While students that expressed a more positive view on the game were more modest in their reported increase of knowledge and interest in programming after playing the game. This can be viewed in the presented results of the study where the average knowledge and interest in programming is almost the same before and after playing the game, while more students reported increase in knowledge and interest after playing the game than students reported decrease. Another potential problem with the closed-ended questions were that some students reported no increase in either knowledge or interest in programming with the motivation that they already liked programming and that the game therefore had no impact in that regard.

It should also be questioned whether one's knowledge can decrease by playing a game, since that would indicate that the game makes the players forget what they already know. Another interpretation of the reported decrease in knowledge is perhaps that those students did not like the game. There were also some indications in the analysis of the closed-ended questions that maybe all students did not understand how the grading scale worked. Some students were positive in the comments of the open-ended questions but had reported decrease in both knowledge and interest after playing the game.

The findings of the study contain both expected and unexpected results. That students favoured consequent gameplay or mechanics throughout the game was to be expected, since this allows the player to focus on the content and challenges of the game and not re-learning how it should be played. Similarly, it was expected that the students do not want the game content to be too difficult. An easy start, or low threshold, is preferred to build confidence and enable a sense of learning or skill progression. However, there are also some unexpected findings in the study's results. It was not expected that students would like the minimal design of the game, although this was not the case for all students, and refer to it as "retro design" given their young age. However, this could be explained by the access to mobile games that often share this design. Further, it was unexpected that students assessed the game in relation to learning games and leisure games. This could be viewed as an indication that the students are accustomed to learning games in school.

An important part of games is challenge, and a progression of challenge, to keep the player in the flow channel. With flow and the flow channel defined by Csikszentmihalyi (1975) as state of peaked enjoyment and energetic focus, in-between border states of anxiety and boredom. The recommendation from UX designers is that game designers should consider the flow state as the optimum user experience and try to keep players in the flow channel (Neal, 2012). However, in this case with programming techniques as an increasingly challenging content, the gameplay challenges must not simultaneously increase. For players without earlier programming and gaming skills, this could lead away from the flow channel towards the state of anxiety.

6. Conclusion

The study shows varying results on students' perceptions of the game, some students like the design and content of the game and some students do not. With the same division, some students perceive that the game engage them and facilitate learning, while other students do not. The conclusion of the study is that there are several important design factors regarding graphics, mechanics, content, learning and engagement to consider when developing a digital escape room game on computer programming. Style and graphics of the game should be familiar to other games that students play. However, this does not necessarily imply state of the art graphics. Many games today, especially mobile, have a minimal and retro design. Gameplay and mechanics should be consistent throughout the game, or at least in the beginning of the game, especially if the game content is directed towards novices. Content, or challenges, of the game should be presented clearly and exciting, with appropriate level of difficulty for the target group. To facilitate learning and engagement, the game should be

perceived as usable by the students. For example, by relating to school content or developing skills of interest and relevance for the students. Lastly, the authors suggest incorporating high level of freedom in the game to facilitate engagement. For example, freedom for player customisation and freedom in world exploration. The study suggests that these design factors, if properly addressed, can support in lowering the threshold for educational escape rooms on programming and raising the ceiling for learning and engagement.

7. Limitations and future research

This study was conducted with a relatively simple game development tool and a limited number of game testers. In the next iteration of game development, this prototype will be rebuilt with a new and more professional game development tool and tested on a larger scale. To test the game's effectiveness for learning programming it would further be desirable to test the game related to learning objectives, for example with the use of a pre- and post-test study design. Another interesting idea would be to include students in the game development process through participatory design. This could potentially allow for early detection of mistakes in the game design, such as it being too text-heavy.

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Toward a learning game on Computational Thinking Driven by Competencies

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Abstract: There are many learning games related to the theme of programming and computational thinking (CT) that exist nowadays. However, the main problem currently in France is that teachers lack training to teach K-12 learners to modern computer concepts. Teachers understand the competencies of referential but are not comfortable with and don't know how to develop teaching sessions for these competencies. Our proposition is: a learning game (LG) driven by competencies will assist teachers to develop teaching sessions with learners. Our main objective is to help teachers to appropriate learning games on CT. To do this, we conducted an analysis based on the PIAF (*Pensée informatique et Algorithmique dans l'enseignement Fondamental* - Computational Thinking in primary school) reference framework which aims at developing CT in elementary school. It lists a set of competencies related to the development of algorithmic thinking in fundamental education. We chose to analyse three existing learning games on CT with this framework. We selected these three learning games ("Blockly Maze", "Compute-it" and "Kodu") from 48 learning games identified on CT. These analyses show that many competencies aren't present in the games. Then we study how to link the PIAF framework in a LG. We work on the learning game named SPY in which the player has to program an agent to escape a maze. Our contribution for this paper is double: (1) an analysis of existing learning games and (2) propositions how to express PIAF competencies in gameplay features.

Keywords: Serious Games, Computational Thinking, Didactic Engineering, Fundamental Education, Learning Game.

1. Introduction and positioning

In 2016 it was established that "40% of Europeans have an insufficient level of digital competencies and that among those who have none (i.e., 22%) 42% are unemployed." (Van den Brande, 2016). This finding shows that learning digital competencies from an early age is crucial because mastering digital tools is becoming essential for all citizens.

In our research context, dealing with education in France, the question of computer science education dates back to the 1970s and is characterized by a balance between two conceptions of what should be taught. On the one hand, there is the idea of teaching IT and computer science as a tool. On the other hand, the idea of computer science as an academic subject, with its own concepts and methods to be taught (Baron and Drot-Delange, 2016).

In France, computer science has made a comeback in elementary school curricula, where it is referred to as "CT". According to Jeannette Wing, CT involves five cognitive abilities: (1) algorithmic thinking, (2) abstraction, (3) evaluation, (4) decomposition, and (5) generalization (Wing, 2006). The French researcher Gilles Dowek (Dowek, 2011) has structured computer science into four concepts so that the content taught provides an accurate picture of the discipline itself: (1) digital information, (2) algorithms, (3) languages, and (4) computing machines. However, teaching CT and computer science in France, at both elementary and high school levels, requires a major involvement from teachers (Kradolfer et al, 2014) in order to tackle this new discipline, due to a lack of training (both pre-service and in-service). Even if teachers don't master CT competencies, they are able to understand the competencies presented inside referential but are not comfortable with and don't know how to

develop teaching sessions for these competencies or to choose the appropriate learning tools/games for these competencies.

Our proposition is: a learning game driven by competencies will assist teachers to develop teaching sessions with learners.

The PIAF[1] competency framework (Parmentier and al, 2020), established in 2021, provides a classification of competencies related to the development of CT in basic education, as well as various pedagogical scenarios to help teachers transmit these competencies to their students. A competency framework is a single underlying construct framework that provides a rational, consistent and practical basis for the purpose of understanding people's behaviours at work and the likelihood of being able to succeed in certain roles and in certain environments (Bartram, 2006). There are already a lot of competency frameworks related to the CT and technology (CSTA K12, Computing, Digital Competencies, …). Parmentier et al (2020) synthesize the content of each framework and propose a synthesis centred on CT and targeted at basic education.

Today there are several dozen LGs dealing with learning programming in various forms (Saddoug et al, 2022). But these games don't explain how competencies are worked on and offer very little freedom for teachers to personalize their activities (Atlan et al, 2019).

In this article, we study a selection of LG meant to teach CT based on the PIAF reference framework. Then we study the possibility of modifying a LG so that it covers the competencies of the PIAF framework.

Next section presents the methodology of the research. In section 3 we analyse three learning games: "Blockly Maze", "Compute-It" and "Kodu". This analysis is based on the PIAF reference framework. We identify the competencies present and those missing in these three games. Section 4 introduces the game SPY and our contribution: we detail how we associate PIAF competencies and game features to design a learning game driven by competencies. We conclude this paper in section 5.

2. Methodology

We followed a didactic engineering research methodology (Barquero and Bosch, 2015). We focus in this paper on the two first phases of didactic engineering: the first concerns preliminary analysis (the analysis of learning games mentioned below through the PIAF competencies) and the second concerns a priori analysis and the design (proposition of a gameplay feature for each PIAF competency). Our goal is to provide a tool for the SPY game (SPY is presented in section 4) that enables teachers to select a set of competencies on CT and automatically build a level on SPY focused on these competencies.

Regarding the first phase, we identified 48 learning games from the review of learning games for CT (Saddoug et al, 2022). This review also combines a list of games identified from reviews related to CT (Lindberg et al, 2019; Miljanovic and Bradbury, 2018; Vahldick et al, 2014). We then focused our analysis on three of them: "Blockly Maze", "Compute-it" and "Kodu", we argue our choices of these three games in the next section.

As we state in the introduction, we choose to base our work on the PIAF framework. It mainly focuses on CT and offers six competencies to be developed with students. Each of these competencies is broken down into a set of three to seven sub-competencies for a total of 26 sub-competencies[2]:

1. C1 - Defining abstractions / generalizing is to develop the ability to name (groups of) objects or actions for later reference.
2. C2 - Compose/decompose a sequence of action aims to develop the ability to manipulate actions to solve tasks.
3. C3 - Controlling a sequence of actions aims to develop the ability to control when a sequence of actions can be performed.

[1] PIAF : *Pensée Informatique et Algorithmique dans l'enseignement Fondamental* (Computational Thinking in primary school)

[2] The complete list of competencies and their descriptions are available on the official PIAF website. https://piaf.loria.fr/en/outcomes/competencies-framework/, accessed May 12, 2022

4. C4 - Evaluating objects or sequences of actions is designed to develop the ability to think about the construction of sequences of actions.
5. C5 - Translate information into different representations should develop the ability to adapt to various equivalent representations
6. C6 - Constructing a sequence of actions iteratively aims to develop a work methodology based on an iterative approach specific to CT.

In next sections, we will refer to a competency as follows: CX.Y which means sub-competency number Y of category number X, for instance C2.4 corresponds to the fourth sub-competency of C2.

To conduct the analysis for the three games mentioned above, we proceeded as follows: Understanding the PIAF competencies, playing the entire games, identifying PIAF competencies worked on, performing a comprehensive analysis, filling in the table of competencies with 0s and 1s (1 if the competency is covered by the game, 0 if not), and lastly analysing results.

Concerning the second phase of the didactic engineering research methodology, we study how to design new game features in the SPY project to cover competencies defined by the PIAF framework. We aimed to establish features that could be enabled/disabled depending on the competencies we wish to work on. We started first by defining which competencies were already present in SPY. If this wasn't the case, or if a competency wasn't represented properly, we have designed new features to integrate it into the game.

3. PIAF based analysis of games dealing with CT teaching

There are already several reviews of learning games for CT in the literature. We conduct our analysis on the work of Saddoug et al (2022) which reviewed the adaptability of a set of learning games meant for teaching CT. This review identifies 48 games. Among these 48 games, we have focused on 3, with complementary features, in order to analyse them with the PIAF framework:

1. "Blockly Maze" (BM) because it is well tested and free software. Indeed, inspired by Scratch (Resnick et al, 2009), BM has been reused in many derivative works (for instance Hour of Code[3], Algorea[4] and more than 400 derivatives on the forge GitHub) and it is well used by teachers. The fact that the game is widely tested has particularly interested us to analyse it based on the PIAF framework.
2. "Compute-it" because it focuses on code reading to teach CT. We considered this game interesting in our study due to its uncommon gameplay structure (executing code rather than writing code).
3. "Kodu" because it was judged as the most adaptable game by Saddoug et al (2022), which highly interested us in our goal of proposing a helping tool for teachers.

3.1 Blockly Maze analysis

In Blockly Maze[5] students are introduced to simple computer programming concepts with a graphical editing tool that uses blocks instead of typed characters. To analyse BM based on the PIAF framework, we identified the competencies covered in each level. For instance, the C5.1 entitled "Represents objects or sequences of actions using a formal representation" consists of "being able to represent an object or an action using a precisely defined mode of representation" (Parmentier et al, 2020). In BM, at level 1 (and this is the case in all levels), several blocks with a precise meaning (linked to an action) have been used to describe a sequence of actions, for example, using the block "turn left" to say that you have to turn to the left.

Table 1: **Analysis of 3 games based on PIAF**

			Blockly Maze	Compute-it	Kodu
PIAF Competencies	C1	1.1	0	0	1
		1.2	1	1	0
		1.3	1	0	1
		1.4	1	1	1
		1.5	1	0	0
		1.6	0	0	1

[3] Hour of Code: https://hourofcode.com/fr/en, accessed May 18, 2022

[4] Algorea: https://algorea.org/main.html#/, accessed May 18, 2022

[5] Blockly Maze: https://blockly.games/maze?lang=en accessed May 19, 2022

			Blockly Maze	Compute-it	Kodu
		1.7	1	0	1
	C2	2.1	1	0	1
		2.2	1	0	1
		2.3	1	0	1
		2.4	1	0	1
		2.5	1	0	1
		2.6	0	0	1
	C3	3.1	1	0	0
		3.2	1	0	0
		3.3	1	0	0
		3.4	1	0	0
	C4	4.1	0	0	1
		4.2	0	0	1
		4.3	1	0	1
	C5	5.1	1	1	1
		5.2	1	0	1
	C6	6.1	0	1	0
		6.2	0	0	0
		6.3	0	0	0
		6.4	0	0	0
Sum	6	26	17	4	16

Furthermore, while trying to test the C6.3 entitled "Correct a sequence of actions to achieve a given goal" in BM, we didn't identify a situation that was proposing a wrong sequence of actions to the player and asking him/her to correct it. So, no levels in BM are designed to work specifically on C6.3 competency. This is the same for C6.1, C6.2 and C6.3.

The results from the analysis showed that there are 17/26 competencies of PIAF covered in the 10 levels of BM (see Table 1).

3.2 Compute-it analysis

Compute-it[6] focuses on code reading. After finishing Compute-it, students will have a good practice on how a computer reads and executes some code. It is a useful competency when discovering code written by other people and to debug his own code. In this game the player has to read code that contains positive and negative conditions, for and while loops, functions and recursivity.

This game is interesting because our analysis points to only 4 PIAF competencies (see Table 1). We noticed C1.2 (i.e., Differentiate atomic actions and non-atomic actions) for levels that contain basic actions and functions. We noticed C1.4 (i.e., Describe the outcome of a sequence of actions) because this competency includes the ability to execute a sequence of action that is the centre of Compute-it. We noticed C5.1 (i.e., Represent objects or sequences of actions in various formal representations) because players have to understand the formal language of Compute-it. We noticed C6.1 (i.e., Test a sequence of actions with respect to a given goal) because executing a program step-by-step is a key competency to test a sequence of actions.

We didn't check C2.X competencies because Compute-it doesn't ask the player to edit a sequence of actions. C3.X are more ambiguous because Compute-it includes control structures but always in a reading perspective and not in a writing perspective as described in the PIAF framework. We can see here that it was difficult to describe Compute-it finely with the PIAF framework.

3.3 Kodu analysis

Kodu[7] is a game aimed at teaching CT as well as creativity, storytelling and problem solving to students, by allowing them to create their own game and edit existing ones. Kodu is based on event-driven programming,

[6] Compute-it: https://compute-it.toxicode.fr/ accessed May 19, 2022

[7] Kodu: https://www.kodugamelab.com/ accessed May 19, 2022

the player defines the actions to associate to a set of events. The events are structured on pages and the player can control the page to execute.

The event-driven programming is an interesting feature of Kodu because it requires a different manner to resolve problems than procedural thinking. For instance, all the C3 competencies are void in Kodu because not applicable of the event-driven programming included in the game. Nevertheless, even if the programming paradigms are different between Kodu and PIAF a lot of competencies have been identified (16/26 see Table 1).

3.4 Conclusions from the analyses

In the three games that we have studied, we found that they don't cover all of the PIAF competencies, each of them has its orientation and its pedagogical choices. We also identified that some games address competencies outside the scope of PIAF like event-driven programming or recursivity. This incomplete analysis shows that even if the three games are about CT the means used to tackle these competencies are diverse.

In the 48 game references identified (Saddoug et al, 2022) none of them explains the links between the targeted competencies and the game mechanics. Within the rest of this paper, we detail how we link the PIAF competencies in the LG we are developing: SPY.

4. How to link competencies and game features?

SPY is a learning game focused on CT. It is an open-source project[8] developed by Sorbonne University. The game principle is to select from a list of actions, those that will allow a robot to get out of a maze. These actions are represented as blocks and the player has to build a sequence of actions before the robot executes them (see Figure 1).

To get out of the maze, the player has to program the robot to avoid obstacles. These obstacles have been built for educational purposes:

1. Sentinels end the level if they spot the robot (if the robot passes through their detection area). Players can select every sentinel to see the sequence of actions assigned to it. Players must know how to read programs, to understand it and to anticipate the sentinels' movements in order to create a proper sequence to reach the objective with the robot.
2. Doors can be activated with terminals. This feature was designed to engage a step-by-step resolution process. Players have to understand that to reach the exit, it is necessary to solve the level in sub-steps (Objective 1: Activate the terminal to open the door. Objective 2: Reach the exit). This also allows players to manipulate the states of an object (open or closed).
3. Program several robots with a unique program. Players need to find a generic solution that enables two robots to reach their exit in different mazes.

In sum, according to Wing (2006), players have to observe and model the simulation (abstraction), decompose their strategy in sub-steps (decomposition), determine the best solution (evaluation), plan the actions to perform (algorithmic thinking) and reuse and adapt previous solutions on new problems (generalization).

Currently a sequence of actions could be created with action blocks: advance, rotate left/right, U-turn, activate and wait; and with control blocks: if condition and for loop. The “if” block is currently limited to one criteria selectable in a drop-down menu (is a wall in front of the robot? Is a sentinel in front of the robot? …).

SPY loads levels from XML files, in this way, it is possible to customize the pedagogical scenario by changing levels order. The levels being in XML format, it is possible to create new levels or to modify those already existing. Currently SPY doesn't include a level editor to help to create new levels or update existing ones, so editing XML files is only accessible for users who know XML format. We used this prototype to implement new features and modify existing ones to improve them.

[8] SPY: https://github.com/Mocahteam/SPY, accessed May 19, 2022

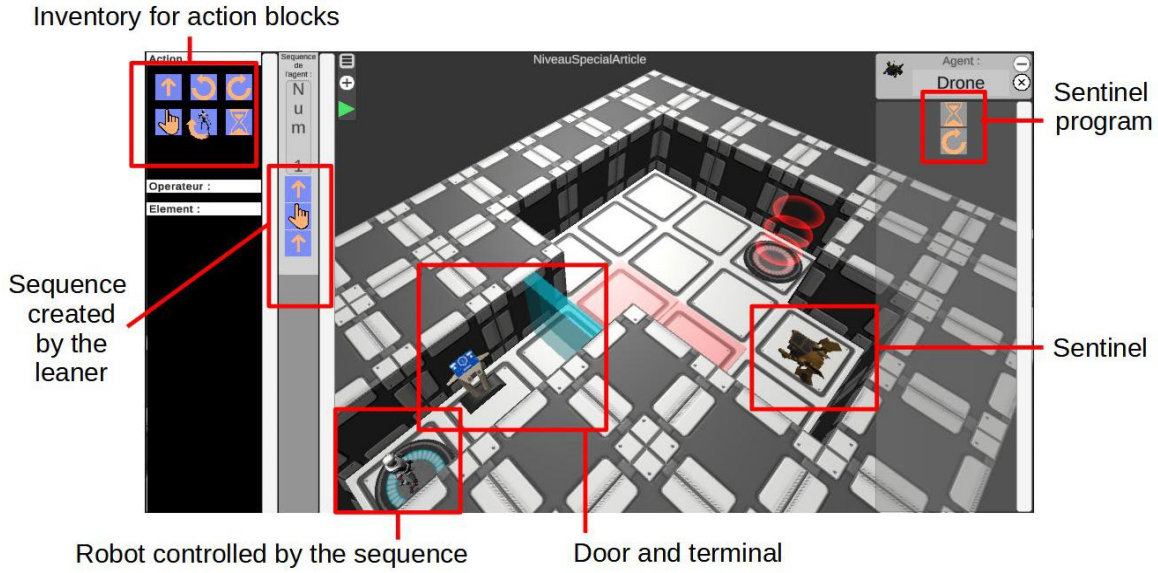


Figure 1: SPY example level

We have designed features for each of the competencies offered by PIAF. We propose 22 features for the 26 PIAF competencies. We remind the goal of this research: providing a tool for the SPY game that enables teachers to select a set of competencies on CT and automatically build a level on SPY focused on these competencies. The list of the 22 features is: F1: Enable library; F2: Enable only required actions; F3: Drag and Drop elements; F4: Initialize robot with an incomplete starting sequence; F5: Enable step by step resolution; F6: For loop; F7: If Else; F8: Play button enabled; F9: Name robot and container to associate them; F10: Select the appropriate actions to solve a level; F11: Ask question according sequence executed by the robot; F12: Select the appropriate sequence to solve a level; F13: Paint the robot and colour detector; F14: Select sequence(s) from history; F15: Provide specific sequence(s); F16: While loop; F17: Operator (And, Or, Not); F18: Select the appropriate exit; F19: Enable several exits + distance criteria; F20: Select an icon to save custom sequence actions; F21: Console mode; F22: Select wrong blocks.

Table 2: Relations between the features and the PIAF competencies

		Features																					
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
PIAF Competencies	C1.1									O													
	C1.2	O																					
	C1.3										O												
	C1.4											O											
	C1.5												O										
	C1.6													O									
	C1.7														O								
	C2.1		O	O																			
	C2.2			O	O																		
	C2.3			O																			
	C2.4			O																			
	C2.5			O												O_1							
	C2.6					O																	
	C3.1						O																
	C3.2																O						
	C3.3							O															
	C3.4																	O					
	C4.1																		O	O			
	C4.2												O							O			
	C4.3			O												O_2				O			
	C5.1																				O		
	C5.2																					O	

	Features																					
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
C6.1								O														
C6.2															O_3							0
C6.3			O												O_3							
C6.4			O											O								

O_1: Incomplete sequences O_2: Non optimal sequence O_3: Sequence with bugs

Table 2 shows a list of the established features and the PIAF competencies they correspond to. The white and grey features were already present in the first version of the game, but the grey features need to be modified to better match the competencies. The black features correspond to the proposed new features.

We can't detail all the new features we designed but we focus in some of them:

1. F9 asks the player to give a name to the robot and the container of actions in order to associate them. If a container and a robot have the same name, the actions inside this container will control the associate robot. Thus, we link this feature to the C1.1 competency (i.e., Name objects and (sequences of) actions) which is defined as "Being able to give names to objects, actions and sequences of actions".
2. F13 provides an action to paint the robot with a specific colour. The player will have to use this action to enable the robot to pass through magic doors that let enter only objects with a specific colour. We link this feature to C1.6 competency (i.e., Using objects whose value can change) that refers to the notion of variables. In our case the robot can store a property (the colour) that can be read by the door.
3. F20 allows the player to save a sequence of actions he has created. When he saves it, he has to associate an icon with it (from a selection offered by the game). The icon is then added to the list of available blocks and the player can use it to create new sequences. When the icon is read during the execution of the sequence, the robot performs the sequence of actions associated with the icon. We associate this feature to the C5.1 competency (i.e., Represent objects or sequences of actions in various formal representations).
4. F22 shows the player an erroneous sequence of actions to solve a level. Then the player has to select the erroneous blocks in the sequence. We associate this feature with C6.2 competency (i.e., Check a sequence of actions with respect to a given goal).

We can see in Table 2 that only two competencies used exactly the same features. The competencies C2.3 "Create a sequence of actions to reach a simple goal" and C2.4 "Create a sequence of actions to reach a complex goal" both represent the creation of sequences. The only difference is that C2.4 is about more complex problems. We explain this similarity in next paragraphs. As discussed in Section 3, we didn't identify any research that details in existing games how the relationship between competencies and game features was designed. Table 2 shows the features we associate to PIAF competencies in the SPY game. But we identify that these associations reveal additional constraints. Indeed, we have constraints between PIAF competencies (for instance the framework states that C2.3 is an extension of C2.1) and constraints between features (for instance "Enable library" is required to "Drag and drop element"). Table 3 summarizes these constraints and we will detail some of them.

Table 3 has to be read line by line. The symbols "||" mean: if a row competency is selected, at least one of the column competencies must be selected. The symbols "&&" mean: when a row competency is activated, all column competencies must be selected. An empty cell means: the row competency is compatible with column competency, the both competencies can be enabled at the same time. The symbols "x" means: when the row competency is selected the column competency is in conflict, the both competencies cannot be selected at the same time.

We can see that for some competencies (C1.3, C1.4, C1.5, C4.1, C4.2 and C6.2), the lines are entirely filled with "x". These competencies are not based on writing a program but require to identify an error, to select a specific answer, to analyse the result of a program, etc. To deal with these competencies we propose specific game features. For instance, C1.3 "Identify the input parameters of a sequence of actions" will be processed by presenting a situation to the player and asking him/her to select required action blocks to resolve this situation but s/he will not have to build a sequence with these blocks (this concerns the competencies C2.X). Then C1.3 will be a specific activity to select a set of blocks without using them and can't be combined with other competencies with SPY. We followed the same process for C1.4, C1.5, C4.1, C4.2 and C6.2.

As we introduce before, "x" symbol refers to incompatible competencies combinations with SPY. This incompatibility is symmetrical. This can be explained by constraints between competencies (e.g., C2.3 and C2.4). If the teacher wants to work on the creation of a sequence of actions to resolve a complex problem (i.e., C2.4), then competency C2.3 (i.e., create a sequence of actions to resolve a simple problem) is not compatible. But this can also be explained by the features. For instance, C2.5 asks to reach an objective by combining already known sequences. This competency requires to use and combine only sequences of actions and exclude features that enable to use action blocks. At the same time C2.2 (i.e., complete a sequence of actions to reach a simple objective) asks to add missing actions in a given sequence without using already known sequences. These two features (i.e., use only sequences and use only action blocks) are mutually exclusive.

The symbols "&&" and "||" mostly work symmetrically. For instance, C6.1 requires at least one competency between C1.7, C2.1, C2.2, C2.3, C2.4, C2.5, C4.3, C5.2, C6.3 and C6.4 that are marked with "||". This is because C6.1 (i.e. check if a sequence of actions reaches an objective) is integrated into SPY by activating the run button that enables to play and check a sequence of actions. This competency cannot be worked on alone. It is necessary to combine it with a competency that requires code execution, C2.2 for instance (i.e. complete a sequence of actions to reach a simple objective). In consequence working on C2.2 requires being able to check if a sequence of actions reaches an objective and then requires C6.1 that is coded in Table 3 by “&&”.

We identify some cases where “&&” and “||” are not symmetrical. For instance, C3.4 (that enables the use of AND, OR, NOT operators) requires at least C3.2 (i.e., “while” loop) or C3.3 (i.e., “if” block), but “&&” symmetry is not true. Indeed, it is possible to work on C3.2 or C3.3 without working on C3.4.

Table 3: Relationships between competencies depending on underlying game features in SPY

	C 1.1	C 1.2	C 1.3	C 1.4	C 1.5	C 1.6	C 1.7	C 2.1	C 2.2	C 2.3	C 2.4	C 2.5	C 2.6	C 3.1	C 3.2	C 3.3	C 3.4	C 4.1	C 4.2	C 4.3	C 5.1	C 5.2	C 6.1	C 6.2	C 6.3	C 6.4
C1.1			X	X	X													X	X				&&	X		
C1.2			X	X	X			||	||	||	||	||		||	||	||	||	X	X	||	||			X	||	||
C1.3	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C1.4	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C1.5	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C1.6			X	X	X					X	&&							X	X					X		
C1.7			X	X	X													X	X					X		
C2.1		&&	X	X	X					X	X	X						X	X				&&	X		
C2.2		&&	X	X	X							X						X	X				&&	X		
C2.3		&&	X	X	X	X		X			X	X		X	X	X	X	X	X				&&	X		
C2.4		&&	X	X	X	||		X		X		X		||	||	||	||	X	X				&&	X		
C2.5		&&	X	X	X			X	X	X	X							X	X				&&	X		
C2.6			X	X	X													X	X				&&	X		
C3.1		&&	X	X	X					X	&&							X	X					X		
C3.2		&&	X	X	X					X	&&							X	X					X		
C3.3		&&	X	X	X					X	&&							X	X					X		
C3.4		&&	X	X	X					X	&&				||	||		X	X					X		
C4.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
C4.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
C4.3		&&	X	X	X													X	X				&&	X		
C5.1		&&	X	X	X													X	X					X		
C5.2			X	X	X													X	X				&&	X		
C6.1			X	X	X		||	||	||	||	||	||						X	X	||		||		X	||	||
C6.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
C6.3		&&	X	X	X													X	X				&&	X		X
C6.4		&&	X	X	X													X	X				&&	X	X	

5. Conclusion and future perspective

In this paper we analysed three learning games to identify the implementation of PIAF competencies in each game. We found that not all competencies were present. But we were able to see that the ways in which these competencies were addressed were diverse. None of them, however, explain the links between the competencies targeted and the associated game mechanics.

Our contribution is to propose a set of features for a specific learning game, each feature is linked to one or several PIAF Framework competencies. In this way, we have identified different types of constraints related to the combination of competencies and features. These constraints have an influence on the pedagogical scenario that teachers can create. Some of the competencies they choose prevent them from selecting others at the same time, and some of the competencies they choose force them to also select other competencies at the same time.

We followed a didactic engineering research methodology. We focused in this paper on the two first stages of didactic engineering: the first is a preliminary analysis (the analysis of learning game mentioned above in view of PIAF competencies) and the second is the design and a priori analysis (proposition of a gameplay feature for each PIAF competency). Future works will focus on phases 3 (observation and data collection) and 4 (a posteriori analysis) and will engage the iterative process of didactic engineering research methodology.

Concerning the two first stages (preliminary analysis and design) we identified two main challenges. The first is a classic game design subject and consists of finding the right game concepts associated with each competency. The second is to create game mechanics that are the most independent from each other, but can be used together.

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Creating an Escape Room for Cultural Mediation: Insights from *"The Archivist's Dream"*

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Abstract: The Archivist's Dream („Der Traum der Archivarin") is a Live Escape Room Game that has been developed by the University of Krems' Center for Applied Game Studies on behalf of the Archives of Contemporary Arts in Krems, Austria, which are dedicated to collecting pre-mortem bequests and post-mortem estates of outstanding artists. Located in the underground facilities of the archive, the Escape Room interweaves selected archival materials, historic media devices and archivist approaches to form an interactive puzzle experience. However, it is not an interactive exhibition showcasing the archives' contents; and while the Escape Room incorporates elements of educational game design, it is an example for a less common application of (Escape Room) Games: the use of game design in the field of cultural mediation (*Kulturvermittlung*). Instead of following an educational goal in the narrower sense, the Escape Room is designed to turn aspects of cultural mediation and archival practice into gameplay principles, focusing on letting players explore the tenets of archival thinking rather than on "teachable" content. This is achieved by establishing different levels of (un-)reality players have to travers within the game: players follow a fictional archivist into her dreams, which merge with the real-life archives. In order to "escape" this dream world, players combine archival practices with dream logic to solve a secret tied to actual archival materials, while at the same time dissolving the borders between real life, dream and game.

Keywords: cultural mediation, serious escape room, archives, game design

1. Introduction

The Archivist's Dream has been developed by the Center for Applied Game Studies on behalf of the Archives of Contemporary Arts in Krems, Austria.

The Archives of Contemporary Arts are dedicated to the collection of pre-mortem bequests and literary estates from leading Austrian artists in the fields of music, literature, and architecture. In addition to the archival tasks of preserving, indexing, and displaying the collections, the activities of this institution include conceiving and carrying out research projects and academic conferences and releasing its own publications.

The *Center for Applied Game Studies* examines the complex relationships between play, games and society in theory and practice. It conducts (i) *applied research* by developing game (or game-based) projects to experimentally expand our understanding of how game design can help address today's problems; and (ii) *basic research* on the potentials, limitations and implications of game- and play-related concepts by applying them as epistemological frameworks to various fields, discourses and phenomena.

Both, the Archives of Contemporary Arts and the Center for Applied Game Studies, are part of the Department for Arts and Cultural Studies at the University for Continuing Education Krems (Danube University Krems).

In autumn of 2019, the Archives of Contemporary Arts approached the Center for Applied Game Studies with the proposal to develop an Escape Room Game based on the archive's collection. While the concept development would be part of the project, some details were established at the beginning: the game would take place in the archives' facilities, specifically in their underground visitors/exhibition area; it would accommodate groups of about 3-6 players and would last about an hour; (reproductions of) the archives' materials could (and should) be used as part of the game; a decision would have to be made *which artists* would be featured in the game, as it was assumed that not all artists represented in the archives could also be represented in the game,

at least not in equal parts (it was later decided that the works of composer Friedrich Cerha and writers Julian Schutting and Peter Turrini would feature in the game).

Most importantly, the game's principle aim was defined: as part of the Archive's purpose as an institution for cultural mediation (*Kulturvermittlung*)[1], the Escape Room was intended to be a measure of audience development in the sense of using aesthetic means to foster a curiosity for arts & culture and, more specifically, archival work in the field of arts that might later turn into "interest, audience engagement and, ideally, lasting attachment" (Hoppe & Heinze, 2016, p. 236f., free translation).

With this aim, the Escape Room positions itself at the intersection of cultural mediation and serious games.

However, this intersection is by no means clear-cut and requires some clarification.

1. The field of cultural mediation is itself multi-faceted, and ranges from the most basic means of teaching facts about arts and culture to facilitating social discourse about arts and culture in the broadest sense. For institutions in the arts and culture sector, mediation practices can include showcasing and contextualizing specific contents and materials, fostering and contributing to public debate through events and publications and involving the public in their respective activities in engaging ways. However, the primary aim of *The Archivist's Dream* was to address new audiences by creating an engaging experience that does not require previous knowledge or even interest in archival work or the artists and materials hosted by the Archives.
2. Within the field of serious games, *The Archivist's Dream* is therefore not an educational game in the stricter sense, because its main purpose is not to teach specific knowledge or skills that players gain by playing the game.

Instead, it aims to translate a theme that might not seem relevant to an audience at first into a relatable experience which, in consequence, can lead to authentic interest for the theme. Hence, it might actually be categorized as an "advergame", which might seem counter-intuitive due to the commercial connotations of the term, but when Sawyer & Smith list advergames as a category in their Serious Games Taxonomy (2008), they apply the term to such diverse fields as military recruitment, health awareness or political games, and while they do not explicitly mention the arts & culture sector - which is introduced into the serious games discourse only later (Djaouti et al., 2011) - it is clear how the use of games to make issues appealing for audiences falls into the same basic category. However, this understanding of the term "advergame" closes the circle back to educational games in the broader sense, as this kind of raising interest can well be considered an educational purpose.

2. Design considerations

After a first brainstorming phase, in which a number of narrative topoi and gameplay ideas were explored and rejected for various reasons, it quickly became clear that there were three main problems that had to be avoided.

1. avoiding unclear simplification: there is always some level of simplification necessary and desired when a serious theme is transposed into a game by creating an abstracted *play-version* of the original theme. However, even though this play-version is usually more accessible, often more pleasant and in some cases even safer to engage with than the original theme, the goal is to foster player interest in (or, in some cases, knowledge of) the original theme rather than its play-version. Players must therefore be helped to distinguish which aspects of their experience relate to the original theme, and which relate to its play-version. The way this was attempted in *The Archivist's Dream* was to create several clearly distinguishable layers of immersion, with the innermost layer (the *Dream*) representing the play-version, while the original theme served as an external reference point.
2. avoiding superficiality: while discrepancies between a game's fiction and the game system (cf. Johnson, 2012) are a common problem in many games, this problem is especially profound in serious games, which are particularly dependent on the coherence of their design (Mitgutsch & Alvarado, 2012). Unluckily, Escape Rooms are not usually known to be very coherent, as most of these games rely on the same gameplay features, on which a variety of different themes is superimposed on the level of fictional

[1] As Moersch and Gyger (2012) point out, there is no English term that precisely and comprehensively corresponds to the German term *Kulturvermittlung*. However, the authors have agreed on the term *cultural mediation*, because it best reflects the idea of bridging a gap between public and professional discourses rather than simply communicating or educating on ideas and concepts.

setting, some of which "fit" the logic of the theme better than others. Just like in any other game design project, it is therefore advisable to first work out the theme in detail before committing to a specific format like the Escape Room. This was not the case with *The Archivist's Dream*, which was intended as an Escape Room from the beginning. However, after a number of different conceptual approaches were explored, it soon turned out that archival work was in many aspects akin to "detective work", and that the basic archival skills of attributing, deciphering and contextualizing could easily be translated into game verbs that suited a puzzle-based Escape Room experience.

3. avoiding negativity: another basic challenge for serious escape room design is the fact that an Escape Room, per definition, suggests flight as an appropriate response to the respective theme: while it makes sense to escape the burning nuclear reactor or the totalitarian prison (both may be themes of serious as well as purely recreational Escape Rooms), it might counter the purpose of promoting art, science or literature when the game's goal is to escape from a museum, laboratory or library. While the location to be escaped is implicitly framed in a negative way, it is the *strategies* facilitating the escape that are promoted as positive. However, this should not discourage the use of evocative and immersive locations just because they represent the theme to be promoted; but it is certainly wise to find ways to counteract their deterioration into negative places. In *The Archivist's Dream*, players do not simply escape the physical archive (and, by implication, the world of arts, culture and archival work), but a *dream version* of this world; as a matter of fact, escaping the dream even gets them back to the *real* archives, which are therefore framed as a desirable place. At the same time, the (abstracted) archival skills of attribution, deciphering and contextualizing are promoted as effective (and engaging) means to fulfill this desire.

3. Location, location, location

The Escape Room makes use of the premises of the Archives of Contemporary Arts, which offer rare opportunities for spatial game design due to their location and architectural design. The Archives are situated in a small, modern building at the northern edge of the Campus Krems, which it shares with the Center for Applied Game Studies and other institutions belonging to the Department of Arts & Cultural Studies of the University Krems. While the Archive's offices are located on the building's third floor, the depot and visitor/exhibition space extends over the entire basement area. There are two ways to access the basement: one can enter it from inside the office building, using either the staircase or an elevator, which takes one to the northern entry to the basement, and which is the way that is usually used by the archive's staff; or one can enter the basement from outside of the building, by entering the *Kesselhaus*, a restaurant and movie theater located about 20 meters south of the office building. Inside the *Kesselhaus*'s lobby, there is a flight of stairs that leads into a locker room and from there, through a glass security door, into the basement. This underground space was an obvious location for the Escape Room Game for a number of reasons:

1. the clear separation of the basement area from its surroundings (for security reasons and due to the vulnerability of some of the stored materials, access is closely monitored, and temperature and humidity must be precisely regulated), simplifies many pragmatic issues of game design. For instance, it makes it easier to tie the entering and exiting of the space to the gameplay.
2. The layout of the visitor/exhibition area also easily accommodates the needs of (Escape Room) game design: while the depot is located on the outer edges of the basement, the visitor/exhibition area is at its center and shapes the perception of the space: in its middle, there is a cube of about 10x16 meters, encompassed by a two-meter-wide corridor. Inside the cube, there are four almost identical 'work rooms', two of which accessible from the Northern stretch of the corridor, while the other two are accessed from its south, close to the glass door through which one enters from the locker room and *Kesselhaus*. Each room can be locked separately, as can the glass door. Because of these features, the visitors/exhibition area can easily support the needs of Escape Room design: most importantly, the seclusion of the area allows for a clear distinction between inside and outside, and the separate lockable rooms enable spatial game progress. In effect, there is no need to create an Escape Room space *within* the location, as the location itself can easily be transformed into an Escape Room space.
3. the architectural concept (created by the Austrian architect Adolf Krischanitz) combines the needs of working with archive materials and the demands of semi-public spaces with contemporary interior design: the work rooms are fitted with ceiling-high wooden shelves and equipped with a long table in the middle; the rooms are identical, except that each room was furnished from a different type of wood. This design, in combination with the separation of the basement area, fosters an experience of *a world apart*, which helps to create an immersive gaming experience.



Figure 1: The visitor/exhibition space with the cube, and the two work rooms used for *The Archivist's Dream*

The basic transformation of the visitor/exhibition area into an Escape Room space was therefore rather straightforward: in order to create a dedicated space for the Escape Room while still allowing the archive's daily activities to proceed, the area was divided: the Northern part of the corridor, from where the depot as well as the elevator and staircase can be accessed, was excluded from the game (separated by construction tape, which, contrary to more sophisticated design barriers, signaled immediately that this area was *not part of the game* through its inconsistency with the game world), leaving the long southern stretch of the southern corridor which can be reached from the locker room glass door, and from which the two southern rooms can be entered, which were now part of the game space. Also, the greater part of the western as well as part of the eastern corridor was included in the game, to create distinct spatial areas which would later serve different game purposes. The only major change was that separate keys had to be made for the two rooms and the glass door, as these doors could previously be unlocked with the same master key.

The result was a game space which could be entered from the locker room through the glass door, and which in the game's early stages only contained a U-shaped corridor, while the two rooms adjacent to the passageway could only be unlocked progressively in the course of the game.

4. Serious theme, playful engagement

Regardless of the many discussions about the implications, validity and limitations of the *Magic Circle* concept in game studies (e.g. Salen & Zimmerman, 2004; Arsenault & Perron, 2008; Juul, 2008; Consalvo, 2009; Lehdonvirta, 2010; Zimmerman, 2012), questions of entering and leaving the game world are a crucial part of any game design or play experience. However, in the case of Escape Room Games, the transition into and out of the game gains additional significance because the game does not simply *take place* within the magic circle of the game world, but the game's primary goal is one of *escaping the game world* (albeit only some layers of it); the relation between inside and outside, immersion and escape, and especially the awareness of being inside of a game (sometimes a game within a game) which has to be left in order to beat it becomes part of *playing the* game rather than just *thinking about* the game.

While most games aim to combine a captivating narrative and engaging gameplay, serious game design must also relate these dimensions to whatever serious *theme* determines the purpose of the game. A serious Escape

Room must, in addition, combine these dimensions with the idea of spatial progress. And as most Escape Rooms are not solitary activities, there is also the social dimension of forming a temporal community with others with whom the experience is shared. As all these dimensions evolve around the question how the game relates to the world outside the game, the guiding question (which informs later design, narrative, and sometimes also pragmatic spatial choices) is: how do we enter and leave the game? In other words: the design challenge becomes one of *creating a magic circle* that, once entered, combines the *narrative*, *gameplay*, *thematic*, *spatial, and social* dimension in a meaningful way.

In *The Archivist's Dream*, special care was taken to clearly distinguish all of these dimensions by creating different transition points, resulting in an experience of *layered immersion*. While most games (especially Live Action Games) incorporate these dimensions, they are not always separated as clearly as they are in the case of *The Archivist's Dream*, where each of these dimensions is reflected in another layer of the experience, and each layer must be entered by passing a different transition point.

The first of these transition points is the *Kesselhaus* lobby, where participants are greeted by the game host and the rules of conduct are outlined. Here, participants transition into the *event* as a whole, as it can be booked by a group of people and is marked by a specific time slot and meeting point. This entry point marks the transition between daily life and the particularity of the social gathering.

The second transition point is crossed when participants are prompted to descend the stairs to the locker room where, as they are told, they will find the *game space*. From now on, participants take the role of *players*, who can expect that - within the general rules of conduct outlined before - ordinary life will be (at least partially) suspended and substituted by the affordances of the game world. However, while players are already looking for clues to what form this substitution might take, the substitution itself does not take place before the next transition point.

The third transition point occurs when players come across a laptop (at this point the only object that allows meaningful interaction), on which a simple adventure game can be played. This game is a virtual version of the campus, and the protagonist is an unnamed archivist who is absorbed in solving a specific problem related to the Archives' materials. By playing the digital game, players enter the Escape Room's *narrative*: from now on, they will follow the archivist's story, and while the archivist is by no means the players' avatar or even the primary 'hero' of this story, she serves as a meaningful reference point for the game's narrative.

However, the virtual world of the digital game is not itself a new layer to be entered, but a transitional space to be crossed: the digital game ends when the archivist, instead of going home to rest, secretly enters the locker room (where players are currently playing the adventure game) via the *Kesselhaus* stairs to continue working, but falls asleep in front of her laptop (the same laptop players have found in the physical locker room). The implication is that at the end of the digital game, the moment the archivist falls asleep, players 'awaken' in *the archivist's dream*, which occupies the same physical space they have entered earlier, but which is at the same time a representation of the archivist's mental world.

This is the fourth transition point, at which players start acting within the physical representation of the archivist's dream, and finally start engaging in the actual *gameplay* by entering the game's final layer: the physical and symbolic realm of the Escape Room in the stricter sense.

This strict separation between the games different layers - made tangible for players by the distinct transition points - is central for *The Archivist Dream's* approach to serious game design, as it enables to address the fifth and final dimension (*theme*) in a playful and meaningful way. This *theme* - archival work in the field of arts - plays into the game in two ways: in a first version, it is present as the actual professional field of archivists, which is bound by the complexities of academically sound archival practice and its responsibilities towards the artists and their work, obligated to society and its demands, committed to state-of-the-art methods and procedures and engaged in a critical discourse on art and society. This professional academic field in all its facets is the reference point for the experience as a whole, the 'serious subject' that players can address when playing the game and that provides a meaningful framework for the event.

However, the game's purpose is not to give a detailed and precise account of the professional field in all its aspects, complexities and implications, nor is it intended to introduce players to the practice (and hardships) of

true archival work, but to present them with an abstracted version of archival problems that urges them to employ basic archival procedures, while still allowing them to do so in a playful manner.

Hence, a second version - a *play-version* - of the theme is created that accommodates that purpose by getting players involved with basic principles of archival work and letting them playfully explore the most engaging facets of archival thinking, while not encumbering them with the more serious implications, tedious aspects and professional responsibilities of actual archival work. In other words, this play-version of archival work embodies Gregory Bateson key element of play, namely that "[t]hese actions, in which we now engage, do not denote what would be denoted by those actions which these actions denote." (1973, p. 185f.), allowing us to address serious issues in a less serious and therefore more accessible, safe and pleasant - i.e., *playful* - manner.

While the initial real world theme of archival work in the field of arts stays an outside reference point, this second play-version of the theme is gradually accessed by players when they (i) enter the *Kesselhaus* (leaving their daily lives behind to enter an archives-related event), (ii) descend the stairs to the locker room (entering an actual, physical archive), (iii) play the digital game (shifting from the real world implications of the *archives-theme* into a dreamlogic, in which some aspects of real archival work are preserved, while others are abstracted, distorted or omitted), and finally (iv) 'awaken' in the actual Escape Room Game, which allows them to playfully engage with the theme in a socially embedded, narratively charged physical space that can be navigated through gameplay interactions .

5. Puzzles with a purpose

The Archivist's Dream primarily follows a simple sequential structure in which puzzles have to be solved in linear order (cf. Nicholson 2015, p. 17) , because it was designed with smaller groups in mind (even allowing only one or two players to have a satisfying play experience), and because the target group had to include Escape Room novices, for whom a sequential structure is easier to handle than more complex structures, and who might find it easier to focus on the specific puzzles and the ludo-narrative experience rather than the game's structure.

The puzzle design itself was guided by three basic principles: (1) the puzzles should involve an abstracted form of archival work by requiring players to attribute, decipher and contextualize in order to find the puzzles solutions; (2) they should involve (reproductions of) the archives' materials, however, these materials were to be purposefully distorted within a dream logic, in order to detach them from their actual meaning enough to foster playful engagement with a play version of these materials, while maintaining their actual significance as an external reference point. This design strategy has the additional advantage that players who are acquainted with the materials (there may even be specialist audiences) will not have an advantage over other players, and can still enjoy playing the game); (3) the puzzles should highlight that the artists are part of a *transitional generation*: the last generation to produce art without (the availability of) digital technology, working by hand, with mechanical devices and with analogue audiovisual media. Especially since the short and playful format of the Escape Room cannot adequately represent the archives' artists individually and do justice to their work in all its facets, incorporating these generational features is also a way to acknowledge the artists *in an abstract way*, by making some of their daily working techniques part of the puzzle design. Also, by creating puzzles that involve working with such seemingly obsolete devices and media, the Escape Room can draw the attention to these disappearing cultural techniques and the archives' commitment to preserve them, while at the same time showing that working with old media and technologies is a crucial archival competence.

The puzzles include:

- - *the giant*: in the archives' corridor, players encounter a seemingly oversized wooden display of a man in old fashioned attire. (In fact, it is a true to size representation of the *Riese vom Steinfeld* – or "Giant of the Steinfeld" -, a real-life 19th century celebrity on whom composer Friedrich Cerha and writer Peter Turrini based their 2002 opera of the same name). Filtering through reproduced stage design notes, costume sketches and other materials related to the original production of the *Wiener Staatsoper*, players need to isolate specific data about the giant which must then be used to unlock the door to the first room. This involves *contextualizing*-skills, because players have to understand the significance of the information in the context of the stage production before it can meaningfully be re-contextualized as a solution in the Escape Room setting.

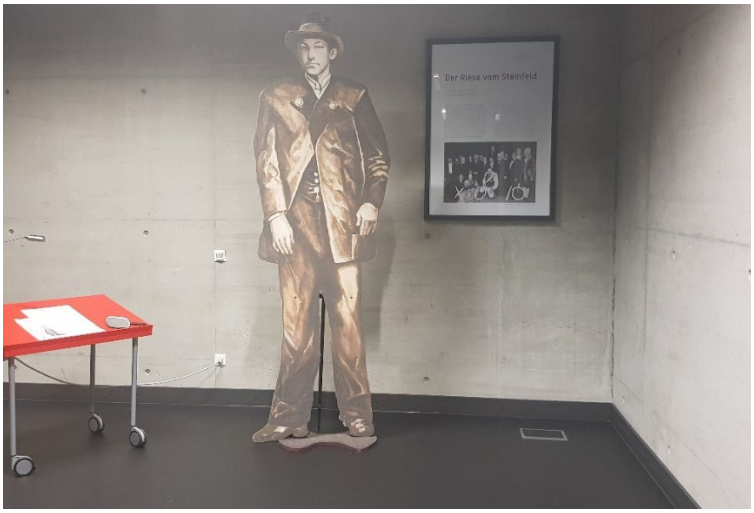


Figure 2: The wooden display of the "*Riese vom Steinfeld"* and the table with the materials from the production of the *Wiener Staatsoper*

- - *little boxes*: in the first room, players find a bunch of (reproduced) materials scattered on a table and must find out which of these materials "belong" to which artist. The intended *dream logic* in this case is one of almost nightmarish quality, as it represents the archivists fear of dissolving order and loss of structure. The materials are then to be put into little boxes (which are actually specialized archival containers used for delicate papers or photographs), which results in a code to be used to proceed in the game. While the obvious skill used here is that of *assigning*, the materials were selected so that relating them to a specific artist first required to relate *another* material to this artist first (for instance, a handwritten note by Julian Schutting contains no further clues to its author, so it can only be assigned after comparing it to the handwriting to another material, whose relation to Schutting is more obvious), so that some form of *contextualizing* was also necessary for this puzzle.



Figure 3: The archival boxes into which scattered materials must be sorted correctly

- - *sound-shards*: players find a number of 1970's audio cassettes in different colors as well as a cassette recorder from the same period. On these cassettes, there are short segments from Friedrich Cerha's musical composition *Spiegel I-VII* ("Mirror I-VII"). Players also find a reel-to-reel tape player as well as an audio reel with the segments arranged in a specific order. The main skill required for this puzzle is a certain type of (auditive) *deciphering*: players now have to listen to the audio reel in order to put the audio cassettes in the right order, resulting in a sequence of colors that corresponds the code of a color-lock which contains the key to the second room.



Figure 4: The reel-to-reel tape player and the cassette recorder.

- - *over his head*: In the second room, players find an overhead projector and (among other things) a number of overhead slides - each showing photographs of the *Riese vom Steinfeld* stage from the *Wiener Staatsoper* production with. In preparation to the actual puzzle, players must identify the correct overhead slide by finding an ultraviolet sign that reveals which of the slides has to be used; also, they have to move the overhead projector onto a specific spot in the corridor and align it correctly. The core puzzle requires them to align the slides so the display is correctly in the context of the stage, which at the same time reveals the key to extracting a code from a number written at the back of the wooden display. This connection depends on a further hint, which also reveals that the wooden display is indeed the actual prop from the opera production, thereby placing the display at the intersection of its different *contexts*: the historical giant and its biography, the opera production and the cooperation between Friedrich Cerha and Peter Turrini, the archives' commitment to meaningfully contextualizing biographical documents, historical facts, artworks, concepts and materials, and, finally, the Escape Room in which these contexts must be considered in order to unlock the secrets of the game.



Figure 5: The slides with the stage photos, waiting to be correctly identified

- - *mirror, mirror, not my type*: Also in the second room, players find an old *Everest*-typewriter (basically the same model Peter Turrini uses, a connection which is made clear in earlier parts of the game). There is a piece of paper in the typewriter with one of Julian Schutting's poems, however, there is one word missing. Earlier, players have unlocked a note on the poem that reveals the missing word, but it is written in Julian Schutting's mirrored handwriting. The main challenge consists in *deciphering* the note, which most players find hard to read even if they use a hand mirror that can be found in a different area. The missing word must now be typed in the typewriter, which reveals yet another word, which is the key to a letter-based combination lock that reveals the next clues.

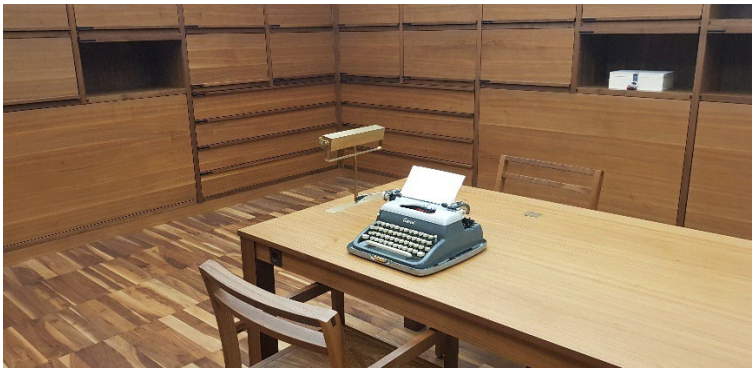


Figure 6: The *Everest*-typewriter in the second room

- - *show(case)time*: the final puzzle to be solved is actually a meta-puzzle that requires clues and materials found as parts of other puzzles. It is a showcase with four compartments, three of which are open. The fourth is closed and contains an envelope whose label makes it clear (with some *deciphering* skill applied) that it contains the last clue needed to finally beat the game. In the course of the game, players have found three exhibition labels which must be correctly assigned to the showcase's compartments (involving *attribution* skill), and which contain hints as to which objects must be placed inside each compartment (which requires a little *contextualizing* skill).



Figure 7: The showcase with the envelope containing the final clue

However, the hints only make sense within the logic of a dream, *and* they require that players have paid attention to the materials found in the course of the game, thereby bringing together the detached world of the dream with the meticulous attitude that is required in real archival work. Once players have identified the required objects and placed them in their respective compartments, the fourth compartment will open and allow access to the envelope, which contains the final key phrase (the solution to the problem that the archivist was looking to solve when she fell asleep in the digital game) that must be entered into the laptop, which will result in the archivist finally waking up and *escaping the dream* - and the players having beaten the game.

6. Conclusion

The Archivist's Dream illustrates the specific demands put on designers at the intersection of cultural mediation and serious games, where design decisions - contrary to game design for pure entertainment - must be based on the demands of the "serious issue" guiding the design process. This is most obvious in the choice of the *theme* itself, which is not a result of, but a precondition for the design process. While this applies to any aspect of the game's design, we have focused on the most prominent aspects of space and puzzle design in this article. The presentation and discussion of these aspects has shown how the demands of the "serious purpose" are on the one hand design limitations which inhibit designers from simply substituting game elements for others that promise more player engagement, satisfaction, or "fun". On the other hand, these limitations can serve as a clear and reliable guiding principle that not only presents additional creative challenges for game designers, but also presents a reliable framework for building an experience that is not only coherent in itself, but also consistent with the serious theme. In effect, and in addition to the separate benefits of enjoyable gameplay *or* educational gain, this can add further layers to the experience by rooting the experience of the fictional game world in real-world domains that go far beyond the experience of the game.

The success of this strategy in the specific application presented here will be evaluated in a separate user study, which will be conducted in the following months, and the findings of which will be reported at a later time.

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Exploring the Combination of Point-of-view and Tenses in Movement-based Design Processes

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Abstract: Our work presented is grounded in Movement-based Design and used for creating solutions with movement as a focal point. Several researchers utilise the moving body in their design for embodied products such as ubiquitous computers and interactive prototypes. The recognition of the moving body is seen in embodied design approaches with a body-centred focused design supporting and encompassing human experience. We believe that incorporating the moving body at the centre of the design process is required to create a future of sustainable movement related to technology, e.g., exertion games, VR or general health and fitness solutions. To understand the nuances of a movement-based design process, we see a need to go beyond the specific design methods. Designers need to approach the complex problem from multiple perspectives. To nuance our movement-based design process, we use the Svanæs and Barkhuus framework to categorise the body-centred design process in two dimensions: Tenses and Point-of-view. The aim is to learn how Point-of-view and Tenses can be utilised to increase the value of the Movement-based Design Process. The empirical material generated in this project stems from two Movement-based Design workshops, each with its own scope: workshop one, the creation of outdoor fitness equipment and workshop two, the creation of technology-based motion games. Both workshops were filmed, and selected participants were interviewed subsequently. The analysis indicated how Point-of-view and Tenses have distinct qualities when interpreted through the framework combined with the empirical material. Point-of-views: 1st-person perspective is used to create insights that are to be shared. 2nd-person perspective is used when two users are designing. 3rd-person perspective creates a distance for analysis. Tenses: Past tense was utilised by watching recorded videos. Present tense creates a feel of here and now, and the future tense was aimed at looking forward in time. The workshops went through several phases, each with its distinct way of working with movement. We wrap up with recommendations for designing a movement-based design process guided by point-of-view and tenses: Start and stay in the 1st-person, let the group share insights, let the participants distance themselves, and the use of tenses should be explicit.

Keywords: Movement-based; Design; Point-of-view; Tense; Design Process, Embodiment, Exertion Games

1. Introduction

The body moves in all aspects of life, and even when it is not moving, movement is happening (Angheloiu et al., 2020). Several researchers use the moving body in design for embodied products such as ubiquitous computers and interactive prototypes (Svanæs & Barkhuus, 2020; van Dijk, 2018; Levisohn & Schiphorst, 2011; O'Brien & Mueller, 2007). Movement is also used in embodied design approaches with body centred design supporting and encompassing human experience via embodied design methods (Höök et al., 2018; Wilde et al., 2017; Svanæs & Barkhuus, 2020; Loke & Robertson, 2013; Höök et al., 2016; Loke & Robertson, 2011).

These approaches and methods have a sensing body in common and a body filled with past experiences, present feelings and aims towards the future. Most importantly, the authors recognise the significance and meaning of the body as a core element in solving complex movement-centred design problems either alone, in a group or through analytical work. Our firm belief is that movement is required as a core element in embodied design to create a future of sustainable movement related to technology such as exertion games, game-based learning, VR or general health and fitness solutions, as proposed, for instance, by Mueller and Young (2018). To design for engaging, exciting and sustainable movement concepts, it is required to incorporate and understand the moving body as the centre of the design process. Thus, we are currently searching for design methods specifically using the moving body, although we are challenged in utilising of the specific method and we, therefore, see a need to go beyond the specific methods.

To understand the nuances of a Movement-based Design Process (MbDP), we see a need to move beyond the specific design methods. Designers need to approach the complex problem of creating future solutions from multiple perspectives and values (Smeenk et al., 2016). The perspectives of point-of-view and tenses are presented by Svanæs and Barkhuus (2020) as a lens through which we can understand body-centred design. Point-of-view and tenses are more valuable as perspectives than using a specific design method for the overall design process (Smeenk et al., 2016; Tomico et al., 2012). The framework proposed by Svanæs and Barkhuus (2020) creates possibilities of understanding by developing a MbDP through applying these perspectives on the

body and exploring from which point-of-view and tense the insights are created. The aim of this paper is to expand the possibilities of future Movement-based Design Processes by using insights gained from applying the lenses of Point-of-view and Tenses in design.

We present how 1st, 2nd, and 3rd-person points-of-view (POVs) have distinct qualities. We found that 1st-person perspective is used in creating insights that must be shared to evolve. 2nd-person perspective can be used when designing solutions including more than one user and was used in sharing insights. 3rd-person perspective creates a distance to analyse the situation. Tenses describe the use of, both past, present, and future. Past tense was used by watching recorded videos. Present tense creates a feel of here and now, and future tense is aimed at looking toward an unknown opportunity.

The paper is laid out as follows. Firstly, we present the theoretical lens through which we understand our design process. Secondly, we present our methodology and methods. Next, we present two cases in which we used movement-based design. We then present an analysis of how points-of-view and tenses were visible in the two workshops. The analysis is divided into phases, with each phase representing a distinct point-of-view and tense being used. Finally, we make recommendations based on our analytical work.

2. Theoretical frame for understanding our design processes

To recognise the nuances of Movement-based Design Processes, Svanæs and Barkshuus' (2020) framework is applied to explore the body as a resource and to make explicit key insights created by the participants. The framework is designed as a 3x3 matrix of two body dimensions: point-of-view and tense.

2.1 Point-of-view in movement-based design

In MbDPs, point-of-view describes the use of three distinct perspectives on the body: 1st, 2nd and 3rd-person (Svanæs & Barkhuus, 2020).

The 1st-person perspective is the person-as-me, described as the body that is me living my life through my perspective (Tomico et al., 2012). This perspective is drawn from the lived body, coined by Merleau-Ponty (2014). The 1st-person view is observed when users focus on themselves and their work. From the 1st-person perspective, users explore their own space independently and develop movements or ideas by themselves without (knowingly) sharing their knowledge with other users.

The 2nd-person perspective is the interpersonal body, the body as you (Svanæs and Barkhuus, 2020). According to Merleu-Ponty (2014), "In creating an awareness of another bodily self, you also create the same awareness in my body." From the 2nd-person perspective, the body is seen as a social phenomenon interacting with other bodies and displaying an innate bodily empathy (Tomico et al., 2012). The 2nd-person perspective is observed when users perform or observe an action to share knowledge or be inspired, either by sharing an artefact, an idea, or a (mirroring) movement.

The 3rd-person perspective is the body seen as an object, the aesthetic body. This is the body one sees in the mirror or the body is seen from the outside (Svanæs & Barkhuus, 2020). Utilising 3rd-person perspective creates a distance to the field in which you are to gain insights by analysing the field (Tomico et al., 2012). The 3rd-person perspective is applied when users view actions to change the action after having analysed it. The 3rd-person perspective is observed when users talk about tweaking an idea to evolve the idea and when users analyse other participants' movements for improvement rather than sharing knowledge, as is the case in 2nd-person perspective (Svanæs & Barkhuus, 2020).

2.2 Tenses in movement-based design

Svanæs & Barkhuus (2020) use tenses to understand what premise creates insights. As a designer, you can be aware of your body in the present. You can also remember the past and how it felt to be you, and you can look to the future and imagine yourself in the future and how that could feel (Svanæs & Barkhuus, 2020). Tenses are applied to describe whether a particular method creates insights from what happened in the past (a memory approach), what is happening now (increasing the awareness of the here and now), or what might happen in the future (focusing on potential and possible outcomes). The three tenses provide the basis for analysing work in MbDPs and from when insights were created, e.g., if the user looked at future possibilities or worked from past experiences.

3. Methodology and study design

We applied a multiple case-study research design to describe, analyse, and understand the users' engagement and actions in the two design workshops. The case study method explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes (Gustafsson, 2017). Using the multiple case-study design process, we gain a greater understanding in MbDPs. Thus, we aim for the investigation to be illustrative of the phenomenon in depth. This qualitative approach requires tools to be used within the contexts (Gustafsson, 2017) as we did in our facilitation having artefacts to be used by the participants. For data generation, we used observation, video recording and interviews. The process of the two workshops produced insights for several different design mock-ups, and in designing these concept proposals, we sought knowledge into and developed the MbDP.

3.1 Methods

To generate data needed to identify key themes and the nuances of the movement-based design process, observations, video observations and interviews were chosen (Thorpe & Olive, 2016).

3.2 Observation

In the first workshop, we participated on equal footing with the users testing movement-based design, and in the second workshop, we distanced ourselves from the process to facilitate. For both workshops the participants were relatively homogeneous and consisted of 20-25 participants who all work with/study movement. Observation provided data on the users' body language, on group dynamics and on how Point-of-view was used in the MbDP. We analysed the MbDP by observing what the users are doing. Hence, we cannot distinguish whether insights were created from the past, present or future tense.

Both workshops were video recorded using wide-angle lenses, encompassing the relatively large area the users designed in, to access details which would otherwise elude our senses and to provide details in social interactions (Heath et al., 2010). The observations revealed two themes. The collaboration between the users was different than planned, and the use of tense was hard to grasp in situ. We explored these themes in semi-structured interviews with five users.

3.3 Video analysis

Transcription of video recordings and the analysis that followed were informed by Heath et al. (2010)'s three-step protocol for reviewing video material. We started with a preliminary review and catalogued the video by transcribing basic activities. We then performed a substantial review looking at distinct phenomena. The organisation of the users' process was further characterised through Svanæs & Barkhuus (2020) framework. To gain insight into the tenses, we interviewed users from each workshop.

3.4 Interviewing users

The purpose of the interview was to create a conversation that invited the users to share accounts of their experiences (Smith & Sparks, 2016). We prepared two pieces of observation footage for each interview and presented the footage to the users. Afterwards, we asked each user to elaborate on what happened in the video. The footage represented a situation where the user did something of interest, e.g., if the user went from working alone to working in a group or played with or presented an artefact for the group.

We analysed tenses by combining the empirical material from the interviews with the suggested characterisation of Point-of-view from video footage.

4. Design cases

The first design workshop was created in collaboration with KOMPAN (a Danish company designing playgrounds and outdoor fitness equipment), and the second workshop was created for The European Conference on Game-Based Learning 2020 (ECGBL2020).

4.1 Designing next-generation outdoor fitness equipment

We were asked to help design Kompan's future playful outdoor fitness equipment. SDU students and designers from the company were divided into five groups (25 participants in totalt); the authors participated in two groups. The company emphasised that the concept must include both a "fun" and "exercise" value and have a

diverse appeal regarding age, gender, weight, and skills. The target group was men and women aged 15 to 50 years. Five mock-ups of outdoor fitness equipment were produced.

4.2 Designing technology-based exercise games

As part of ECGBL2020, we organised a hybrid workshop in which online and physical participants collaborated with attending professors and Sport Science students from the local university (20 participants in total) to ideate and make technology-based exercise game prototypes. The workshop ended with two technology-based exercise games, which were reflected on by the participants.

5. Point-of-view and Tenses in Movement-based Design Processes

5.1 Analysis outcome in short

The analysis of our Kompan workshop and an ECGBL workshop uncovered how users utilised Point-of-view and tense (marked in grey). An overview of the process analyses is presented in Table 1. The process phases are visualised by associated Point-of-view and tenses, and states outcomes and allocated time in the workshop.

Table 1: Each workshop with associated Point-of-view, tense, outcome, and time

Case	Phase	Point-of-view	Tense	Outcome	Time
Kompan	**Phase 1:** Creating a feel for the artifacts in a circle	1st person **2nd person** 3rd person	Past **Present** Future	Experience with different artifacts.	3 minutes
	Phase 2: Observing the group work	1st person **2nd person** **3rd person**	Past **Present** **Future**	One activity involving two active users	10 minutes
	Phase 3: Verbalising thoughts	1st person 2nd person **3rd person**	Past Present **Future**	An analysis and change of users' position in the former activity	3 minutes
	Phase 4: Changing artifacts	**1st person** **2nd person** 3rd person	Past Present **Future**	Using the ball as the main artefact and using the wooden pole	8 minutes
	Phase 5: Balance & Swing	1st person **2nd person** 3rd person	Past **Present** **Future**	Two activities recorded by video	10 minutes
	Phase 6: Voting, building & Pitching	1st person 2nd person **3rd person**	**Past** Present **Future**	An action mock-up in miniature scale + a pitch *Time spent in process: 64 minutes*	30 minutes
ECGBL	**Phase 1:** Tinkering alone	**1st person** 2nd person 3rd person	Past **Present** Future	Experience with different artifacts.	14 minutes
	Phase 2: Group tinkering	1st person **2nd person** 3rd person	Past **Present** Future	Three activities involving the group.	10 minutes
	Phase 3: Analysing & tweaking the game	1st person 2nd person **3rd person**	Past **Present** Future	Selection of one activity and tweaking it.	10 minutes
	Phase 4: Constructing the future game	1st person **2nd person** 3rd person	Past Present **Future**	Enactment of the selected activity.	13 minutes
	Phase 5: Building & Programming	1st person 2nd person **3rd person**	**Past** **Present** **Future**	An action mock-up in miniature scale. *Time spent in process: 67 minutes*	20 minutes

6. Case 1: The next generation of outdoor fitness equipment

The scope of the workshop was to create new ideas for Kompan's next-generation outdoor playful fitness equipment. The group was placed on and around a steel bridge built with webbed rope (See Figure 1).



Figure 1: The bridge of webbed rope

6.1 Phase 1: Creating a feel for the context and artefacts

The group gathered at the bridge (See Figure 1) and utilised the 2nd-person perspective to gain new ideas from observing and responding to each other's movements (actions) in the present tense. As one user of the group recalls during the interview: "We just got on the same wavelength and vibes together without much talking". Phase 1 ended with the users moving toward the bridge after having created a feel for the artefacts in 2nd-person – present tense.

6.2 Phase 2: Observing the group work

Phase 2 consisted of two different activities being developed. The users placed themselves under the bridge in two smaller groups. One group is observing, and one is moving. Phase 2 was an equal mix of 2nd and 3rd-person perspectives. The movement was done by two users playing and sharing insights in a 2nd-person perspective, while three users observed the activity from a distance in a 3rd-person perspective. The observing users are seen in the video footage introducing themselves to the activity via artefacts and changed from 3rd-person to 2nd-person. The moving users tinker with the activity as it progresses while working in the present tense. Alongside the users working in 2nd-person – present, the observing users work in 3rd-person – future as they observe a future activity being played. The observing users analyse the moving users using the 3rd-person – future to evolve the activity into a "better" fit for the situation. Phase 2 ended with one activity physically involving all users.

6.3 Phase 3: Verbalising thoughts

In phase 3, the group utilised the 3rd-person perspective – future tense by verbalising tweaks to the activity. The verbalisation is a way to create a distanced standpoint using 3rd-person perspective. The group passes the ball to each other in a volleyball style—passing, enacting a future ballgame, and using future tense. Phase 3 ends with two users standing on the bridge catching the ball, having also recorded their own activity.

6.4 Phase 4: Change of artefacts

During phase 4, the activity develops from revolving around a ball and tinkering with a wooden pole. The group uses 2nd-person perspective mixed with 1st-person perspective to redefine the activity. The process has a few active users moving and being in 2nd-person – present in the main activity. While some users played with the ball, one user tinkered with the wooden pole in the background, creating a feel of 1st-person – present. The wooden pole is introduced to the users standing on the bridge, which changes the activity. Phase 4 ends with having changed the primary artefact from using a ball to using a wooden pole.

6.5 Phase 5: Balancing & swinging

Phase 5 consisted of two activities, one person crossing the bridge and another working through the bridge. Having introduced a wooden pole, two users are observed holding the wooden pole with rope moving across the bridge, working in a 2nd-person – present and future perspective. The activity evolves as the group verbalise thoughts involving both moving and observing users. Tweaks are done as the balancing activity progresses, such as waiting to throw the ball to help the two users balance and not throwing at full speed.

The users create a future activity while observing each other enacting the activity. Having recorded the balancing activity, two members lie down on the bridge and stick their arms through the braided rope. This second activity was created utilising both 1st and 2nd-person perspectives, as one user recalls in the interview, "There were these holes, and we can actually lie down on the braided rope". The user had created a new feel by lying down. Another user mentions a "common feeling of the situation" in the interview. This user imitates the user lying

down and, in turn, creating the next activity. In this activity, the users lie down, hold the wooden pole, and swing it back and forth. The users had developed a solution by sharing experiences and creating a shared feel of here and now applying a 2nd-person perspective – present tense. Phase 5 ends with the group having recorded videos of two developed activities (one from phase 2).

6.6 Phase 6: Voting, building prototype & pitching

The last phase consisted of three design methods: having the users watch recorded solutions, create a mock-up, and pitch their final solution. The users applied a 3rd-person – past perspective by watching themselves on the recorded video. From a distance, the users analysed the best solution without the need to empathise with movement. One user mentions this distance in the interview by saying, "The concept looks different on video."

When the group builds the mock-up, the work continues in the 3rd-person perspective having to work with objects such as DIY-material like paper, tape, and glue. The users we observed were working on creating an object and a pitch, which would help the group explain their solution to others working in the future tense. Phase 6 ended with all the groups presenting their solution to each other.

7. Case 2: The creation of technology-based motion games

The aim of this workshop was to create technology-based motion games as part of an embodied workshop.



Figure 2: The context in which the process occurs

7.1 Phase 1: Tinkering alone

In phase 1 the users started by working alone to get a feel of a self-chosen artefact. The users move with, on and over their chosen artefact in the context (See figure 2). Working separately, the users create a feel, right here and now for themselves, being in 1st-person - present. Phase 1 ends with one user gathering three hula hoop rings and pulling the rope through them.

7.2 Phase 2: Group tinkering

Phase 2 had three different activities from the 2nd-person perspective. The group shared insights from the previous phase and created an activity resembling tug-of-war over two hurdles with a hula-hoop ring in the middle. The users empathically observed how each user responded to the "dangers" of the wooden ring and changed to a plastic ring working from insights created in 2nd-person - present. The group subsequently moves around, helping each other get the hula-hoop ring to pass the metal bars (See Figure 2) while utilising a 2nd-person – present perspective. The activity evolved a third time keeping the mechanics of moving as a team. The group is observed to pick up a wooden baton and hold it between two users while manoeuvring across the context holding the baton in their hands, connecting the two users. This last activity of phase 2 also utilised 2nd-person – present. Phase 2 ends with the group continuing their work with wooden batons.

7.3 Phase 3: Analysing & tweaking the game

Phase 3 consists of a group discussion utilising a 3rd-person perspective. Due to time constraints, two participants leave the process. The group proceeds with their work on the baton game from phase 2. The group verbalises ways of tweaking the activity from a 3rd-person perspective. After a conversation, one user walks to the metal bars and asks, "Should I just try and walk it?" The other user responds, "either go over or under, just go under", to which another user says, "go to the one behind him". The group utilised a 3rd-person perspective as they analysed the games witnessed. They talk about the game as it happened in the past. The focus of the

conversation is to change the form of the game, here and now, thus utilising present tense. Verbalising the game by talking about whether to walk under or over the obstacle, the group continues work in 3rd-person – present, analysing the game as it proceeds. Phase 3 ended with the group having selected one activity and tweaked it.

7.4 Phase 4: Constructing the future game

Phase 4 consists of playing and recording an activity. One user is observed placing mats, sprint blocks, and discuses, while the other user moves around in the metal bars near the placed artefacts. The users act, talk, do movements and tinker while placing the artefacts. They utilise the 2nd-person – future perspective, thus enacting a possible future together. Afterwards, the moving users return to the start and ask, "Okay, guys. How did it look? I think we need to try with another team." As facilitators, we are invited to try the activity as the opposing team to the two users, enacting a future scenario utilising 2nd-person – future. Phase 4 ended with the group recording a video of the physical learning game created with the facilitators participating.

7.5 Phase 5: Building & programming

Phase 5 consists of three design methods: analysing the game, building a mock-up, and starting a computational thinking process. The group analysed the recorded video of the activity with the intention of building and programming the game into an action-mock-up (a small-scale replica of the game with functioning technological sensors and actuators). The group utilised the 3rd-person – past perspective by analysing the activity for changes. While making the mock-up, the group employed present tense as they analysed the object(s) here and now. Future tense was utilised while enacting the activity via the mock-up. Phase 5 ended with a group reflection on the process, having built a mock-up.

8. Concluding remarks, learning points and recommendations

In the following section, we conclude and provide discussions and recommendations looking further into the use of point-of-view and tenses for future movement-based design processes.

Analysing the two movement-based design processes through the lenses of Point-of-view and tenses helped us understand how the perspectives had been used in designing with movement.

Generally, both 1st, 2nd and 3rd-person perspectives have distinct qualities used in distinct design phases in the design of playful fitness equipment and in the design of exertion games. The 2nd-person perspective we observed being used when the design participants were designing solutions including more than one user and through their sharing of insights. Working in 1st-person creates insights that had to be shared to evolve. In the Kompan workshop, the 1st-person perspective was used to introduce new ideas to the group. In the ECGBL workshop, the 1st-person perspective laid the foundation for the 2nd-person perspective. In both workshops the 3rd-person allowed the users to distance themselves to analyse the situation.

In both workshops past, present and future tenses were utilised. The Past tense was mainly used to look at suggested solutions by watching recorded videos in both workshops. Present tense was utilised in almost every phase of both workshops and seemed to be the main tense in which the users worked. Future tense was mainly used towards the end of the ECGBL workshop as the users had already designed some of the work. Whereas, in the Kompan workshop the future tense was present from phase 2 until the end of the workshop.

In reflecting upon our work, we see that Point-of-view and Tenses has been an implicit part of our movement-based design processes. We now recognise the value of using Point-of-view and Tenses in working with movement-based design activities. As such we will explicit use Point-of-view and Tenses in future movement-based design processes and in the following section we present our recommendations.

8.1 Start and stay in 1st person.

In future workshops, we recommend utilising the 1st-person perspective more extensively, thereby ensuring insights created is from a felt, lived experience based on current and past experiences when designing for sustainable movement. In the Kompan workshop, 1st-person Point-of-view was used sporadically, while in ECGBL2020, we utilised 1st-person to a larger extent before sharing knowledge. In their paper on Moving and Making Strange, Loke and Robertson (2013) use 1st-person perspective in three out of seven steps, making this perspective a larger part of their design process than we did in our MbDP. Focusing on 1st-person perspective ensures that the essential felt and lived experience of movement is considered in future design (Loke &

Robertson, 2013). Likewise, Tomico et al. (2012) argue that utilising 1st-person perspective provides a commitment and intrinsic motivation; thus, design participants gain a sense of responsibility for the process.

In both workshops, we began the process by utilising 1st-person perspective, having the users work alone and with their own approach towards artefacts in the given context. Much like Loke & Robertson (2013), the users quickly move from 1st-person onto 2nd-person, only returning to 1st-person sporadically. Having used the 1st-person perspective more extensively in the movement-based process could have benefited from the intrinsic motivation and the users' commitment to a larger degree.

8.2 Let the group work together but…

We recommend using 2nd-person perspective in more than one design phase. The sharing of insights is valuable and exchanging information between users provides opportunities for evolvement of the design (Tomico et al., 2012).

In the interviews, participants expressed a sense of excitement upon working together. Segura et al., (2016) point toward the value of embodied design as creating high engagement, arousal and positive emotions when working together by shaping space to support mutual orientation, awareness, and communication. In both workshops, the groups tended to go back and utilise the 2nd-person perspective working collectively. Each time a group worked in either 1st or 3rd-person, they would return to share their knowledge with the group.

This sharing of knowledge was done in three ways: 1) participants verbalised their insights to each other to evaluate, 2) participants evolved the past activity and 3) members of the group let go of their activity and joined up in pairs or, as a whole group, gave up their own work. However, Loke and Robertson (2013) and Segura et al., (2016) recommend utilising 1st-person perspective before sharing insights to ensure that the essential felt and lived experience of movement is considered. This could be done by making sure to separate the participants in the facilitation.

8.3 Let the participants distance themselves

Like Segura et al., (2016) movement-first approach our recommendation for the future movement-based design process is to utilise the 3rd-person perspective in the last part of a workshop to create a distance between the users and their proposed solution as late as possible and to facilitate as much intrinsic motivation as possible.

Utilising the 3rd-person perspective users can distance themselves from the process by analysing the others. In our workshops, this was done either by verbalising their thoughts or commenting on movement as it unfolds to make it better. According to Tomico et al., (2012) the 3rd-person perspective can provide a holistic view of the situation by having the users distance themselves and look objectively at their solution.

8.4 Tense in movement-based design should be clear

We recommend future movement-based design processes make the purpose of tense clear for both the users and the facilitator creating the process. Thus, designers should make more conscious choices as to when insights should emerge. Past tense supports insights usually taken for granted and makes them mouldable for the design process. Generally, the design process is seen as a discipline oriented toward the future that rests on the conditions of the past (Soro et al., 2019). When users work with the interplay of future and past, they is explore a feeling of here and now, working subconsciously with their own past experiences while trying to define the future (Svanæs & Barkhuus, 2020).

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Learning Machine Learning with a Game

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Abstract: AIs playing strategic games have always fascinated humans. Specifically, the reinforcement learning technique Alpha Zero (D.Silver, 2016) has gained much attention for its capability to play Go, which was hard to crack problem for AI for a long time. Additionally, we see the rise of explainable AI (xAI), which tries to address the problem that many modern AI decision techniques are black-box approaches and incomprehensible to humans. Combining a board game AI for the relatively simple game Connect-Four with explanation techniques offers the possibility of learning something about an AI's inner workings and the game itself. This paper explains how to combine an Alpha-Zero-based AI with known explanation techniques used in supervised learning. Additionally, we combine this with known visualization approaches for trees. Alpha-Zero combines a neuronal network and a Monte-Carlo-Search-Tree. The approach we present in this paper focuses on two explanations. The first explanation is a dynamic analysis of the evolving situation, primarily based on the tree aspect, and works with a radial tree representation (Yee et al., 2001). The second explanation is a static analysis that tries to identify the relevant situation elements using the Lime (Local Interpretable Model Agnostic Explanations) approach (Christoforos Anagnostopoulos, 2020). This technique focuses primarily on the neuronal network aspect. The straightforward application of Lime towards the Monte-Carlo-Search-Tree approach would be too compute-intensive for interactive applications. We suggest a modification to accommodate search trees and sacrifice the model agnosticism specifically. We use a weighted Lasso-based approach on the different board constellations analyzed in the search tree by the neuronal network to get a final static explanation of the situation. Finally, we visually interpret the resulting linear weights from the Lasso analysis on the game board. The implementation is done in Python using the PyGame library for visualization and interaction implementation. We implemented the neuronal networks with PyTorch and the Lasso analysis with Scikit Learn. This paper provides implementation details on an experimental approach to learning something about a game and how machines learn to play a game.

Keywords: strategy games, reinforcement learning, explainable AI

1. Introduction and related work

AI and precisely machine learning became a field of increasing importance during the last decade (see [Makridakis, 2017]). Machine learning, specifically reinforcement learning (RL), has gathered much attention with the success of Go-playing programs. Many modern AI decision processes though powerful, are unintuitive and unexplainable. This paper aims to implement an explanation technique for the relatively simple board game Connect-Four. The game player can learn something about the applied reinforcement learning technique and the game itself. Therefore, the point of this paper is to implement a combination of explanation techniques for a Connect-Four playing AI. With increasing power in AI, the balancing problem of performance and explainability becomes evident. In the end, a human must burden with the responsibility of the decisions made. [Dosilovic et al., 2018] have given a good overview of this problem and the general approaches to explainable AI. Reinforcement Learning for board games incorporates a mixture of deep neuronal networks and search trees, as [D. Silver, 2016] explains. Silver [Silver et al., 2017] also generalized this approach in the concept of the Alpha-Zero AI to two-person board games of perfect information in general. This paper uses Connect-Four as an experimentation platform to explain the Alpha-Zero AI. The game of Connect-Four is well understood and theoretically solved, as explained by Allis [Allis, 1988]. The game's limited complexity and ease of understanding make it a perfect playground for explainable AI by a developer. It does not require domain-specific knowledge like real-world applications like medicine (see [Rokosna et al., 2020], for instance). The limited search space of that game, especially in comparison with Go, would make this game more suitable for an AI-based on the Alpha-Beta family [Schaeffer, 1989]. On the other hand, the game's reduced complexity makes experimentation with explanation components for an Alpha-Zero-based AI more convenient. The Alpha-Zero AI combines a deep convolutional residual net [He et al., 2015] and a Monte-Carlo-Search-Tree [Browne et al., 2012]. The neuronal net uses two heads, resulting in the current game situation's value and a policy on which actions to take. Both pieces of information are incorporated into the search tree approach to get upper confidence bound estimation of the value of the current situation [Rosin, 2011]. Alpha-Zero falls into the category of RL techniques. A good overview of explanation approaches for RL is given in [Puiutta and Veith, 2020]. The explanation approach we present in this paper would fall into the post-hoc model category with a local scope. The explanation system we implemented falls into two subcomponents: a dynamic and static analysis. The dynamic analysis displays an interactive version of a subtree of the Monte-Carlo search tree. We plot this tree in a radial layout fashion (see [Yee et al., 2001], [Huang et al., 2020]). As several different moves may lead to the same board constellation,

the tree may become a directed acyclic graph. Zobrist style hashing technique [Mason et al., 2005] identifies identical game situations. The main contribution of this paper is the static analysis of the game board. We base the static analysis's core concept on Lime's approach (Local Interpretable Model Agnostic Explanations) [Ribeiro et al., 2016]. This approach has also become popular lately in the simulation community, as explained by [Christoforos Anagnostopoulos, 2020]. The general idea of Lime is to observe changes in the response of a learning system towards a locally perturbed stimulus. A simplified model then describes this response. Picking a linear model with an L_1-based regularization called Lasso [Tibshirani, 1996] is a popular choice in this context.

We analyze the situation by fitting the Lasso model to the value estimation of the Alpha-Zero AI. Doing a Lime analysis for a decision process requires computing the decision process several times. In the context of Connect-Four, this is in the order of magnitude of 100 situations as the board has 42 positions. Considering that one analysis with the search tree may already take longer than 100 ms, this is not an option. The performance problem may become relevant if one wants to apply the approach to more complex games. As a solution, we apply a Lasso analysis toward all relevant board constellations covered by the decision tree and use a weighted Lasso analysis [Bergersen et al., 2011] to get to the final estimation. The probabilities of the situations to occur determines the weights. The trick is that evaluating a neuronal net for several prior known inputs is cheaper than doing many individual evaluations that depend on the tree search results. The independent evaluations can be done on the GPU in parallel (see [Gu et al., 2014]). As the last step, we turn the resulting linear coefficients into a meaningful visualization of the game situation. We implemented the game and the analysis component in Python. For drawing the game board and the tree, we use the library PyGame [Shinners, 2011]. We use PyTorch [Paszke et al., 2019] for the neuronal network part. The Lasso approximation for the Lime analysis is made with Scikit-Learn [Pedregosa et al., 2011]. The remaining of the paper is structured as follows. In section 2, we will discuss the dynamic analysis of the game. Section 3 follows the static analysis of the Lime-based approach. Section 4 shows some results of the two explanation components. Finally, we will discuss some extension possibilities and future work in section 5.

2. Dynamic Analysis

The objective of the dynamic analysis is to display the potential development of the current situation. This analysis is closely related to the Monte-Carlo-Tree-Search (MCTS), one of the Alpha-Zero AI pillars. The tree is expanded node by a node in an iterative fashion. In our case, we use 100 expansion steps. Every MCTS consists of three rules. The first is the node selection for expansion, the second is the leaf evaluation, and the third is the propagation rule up the tree. In the case of Alpha Zero, every edge contains the number of visits and the q-value. The q-value is the long-term value of the corresponding action chosen in that situation. An upper bound confidence selection makes branch selection. The number of visits, the q-values, and the policy determines the upper confidence bound value. The leaves are evaluated either by the final game outcome or the neuronal net.

We evaluate the total number of visits per node and edge for the tree's visualization. The nodes and edges visits estimate the probability of that situation occurring. We use that information to prune the tree to a smaller version as a first step. We eliminate all nodes of a probability smaller than 10%. The tree's nodes and edges bear the player's color that takes a turn in that situation. We visualize the situation's probabilities and the transitions with the thickness of the nodes and edges. We radially display the tree where only a 90-degree angle is covered. The user can select nodes in the graph by picking. We indicated the selected node by rendering a square and displaying the corresponding situation on the left pane. The state value and the q-Values are shown in the player's color in the two headlines above that board. Below we display the transition probabilities. We render the transition probabilities that we have included in the graph in green. The left to right order in the graph corresponds to the slot order on the board. Fig. 3 is an example of the visualization. We took special care of the situation that different sequences of actions may lead to the same situation. Alpha-Zero takes care of this problem by keeping a Zobrist-style hashing table of the game boards. We take care of this by accounting for unique edges in the visualization tree that turn the tree into a directed acyclic graph. We display such a situation in fig. 1.

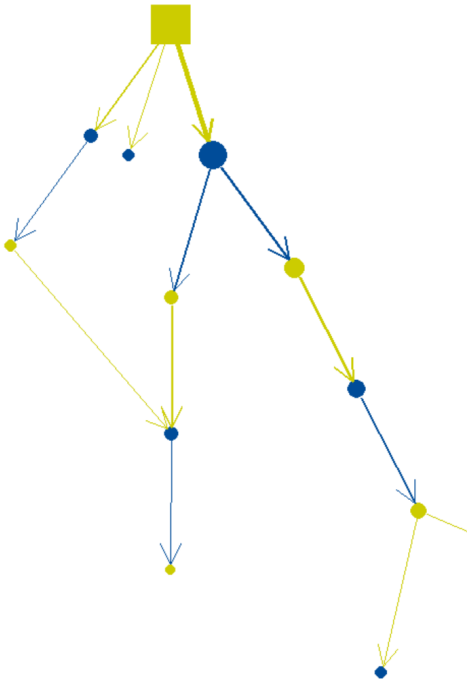


Figure 1: This figure shows an example of a degenerated tree. The same game situation is reached over two different paths.

3. Static Analysis

The static analysis is the main contribution of this paper. This analysis aims to visualize the current and probable future situation elements contributing most to the current situation evaluation. As explained in section 1, we derive the approach mainly from the Local Interpretable Model Agnostic Explanations (Lime) approach. The idea of Lime is to find a simplified model that describes the behavior of a target value in the vicinity of an input value. A summary of the description [Ribeiro et al., 2016] is as follows. Let the model we want to describe be given by $f: \mathbb{R}^d \rightarrow \mathbb{R}$. We are looking for $g \in G$ as an explanation where G is the class of potentially interpretable models. Let $\Omega(g)$ be a measure of complexity. For a linear model, Ω may be the number of non-zero weights. As determining this is an NP-complete problem, an L_1 regularized solution is often suited as an approximation [Tibshirani, 1996]. Let $\pi_x(z)$ be a proximity measure between x and z. Let $L(f, g, \pi_x)$ be a loss function describing how well g approximates f in the locality described by π_x. In total, we try to find $\xi: \mathbb{R} \rightarrow (\mathbb{R}^d \rightarrow \mathbb{R})$.

$$\xi(x) = \underset{g \in G}{argmin}\, L(f, g, \pi_x) + \alpha \cdot \Omega(g) \qquad (1)$$

The α factor appears in the Lasso approach as the L_1regularization factor. In our case, $\alpha = 0.0005$ turned out to be valid. However, two questions arise when we try to apply this to our problem. The first question is the vicinity π_x, and the second question is the computational time needed if we would like to sample the complete Alpha Zero AI with the MCTS system several times.

As for the first question, we have chosen to perturb the existing situation by replacing existing stones with the opposite or no stone. We do the perturbation for exactly one position each. If we have n stones on the current board constellation occupied, we will get 2n variations. We have chosen not to perturb the empty spaces. The player can only place stones on top of the current row. If we would perturb all empty spaces, we would also analyze impossible board configurations. As for stones being placed in the potential future, this issue is solved in combination with the second problem: the computational time needed. The complete Alpha Zero AI evaluation for one constellation takes more than 100ms, rendering the Lime approach to the total solution impossible. Instead, we include the board constellations of every node in our analysis if the probability of this situation occurring is at least 1%. Consequently, we still need to evaluate the neuronal net for our target

objective's values f several times, but the net input values do not depend on each other. The independent evaluation allows for efficient batch processing on the GPU. As we have explained in section 2, we estimate the probability for the situation to occur. We use this probability as a weighting factor in our Lasso analysis. [Bergersen et al., 2011] describe the weighted Lasso analysis. As the last step, we need to visualize the results of the Lime analysis in combination with the game board in a meaningful way. Let us start with the game board.

We can use the fact that once a stone is placed in Connect-Four, it will remain there till the end of the game. Consequently, we can render all the stones of the root node the traditional way. As for the other stones that may be placed in the future, we render only those stones that the Lasso algorithm has selected by assigning non-zero linear weights. We build the average of the eventual future game boards weighted by their probability of happening for those positions. This probability gets mapped to the saturation of the stone color. A white circle is included in the visualization to mark this explicitly as a potential future stone. As a next step, we visualize the linear regression coefficients of the Lasso analysis. The individual coefficient gets multiplied with the stone index −1 for hostile stone and 1 for one's stone. A positive regression coefficient for the respective stone position means that it would be good if that stone would be the player's stone, and a negative would mean it would be better if it were a hostile one. If the regression coefficients and the stone match in signs, it is suitable for the current player and otherwise deficient. As an input for the visualization, we can use the product of the linear regression coefficient and the stone coefficient. The current value of the situation is displayed on top of the game board. Sample visualizations can be found in fig. 4 and fig. 5. Fig. 2 summarizes the Lime-based static analysis's overall data flow. We start with the annotated tree, which results from the Alpha-Zero AI. Here we extract all relevant future situations with their probability. This information goes directly into the Lime Analysis to perturb all different game boards and the weighted board's averager. The probabilities of future boards and the perturbation results go into the Lasso analysis. The results of the Lasso analysis form in the combination of the average board and the visualization elements. The weighted average board itself generates the image of current and potential future stones. The Lasso component filters the potential stones.

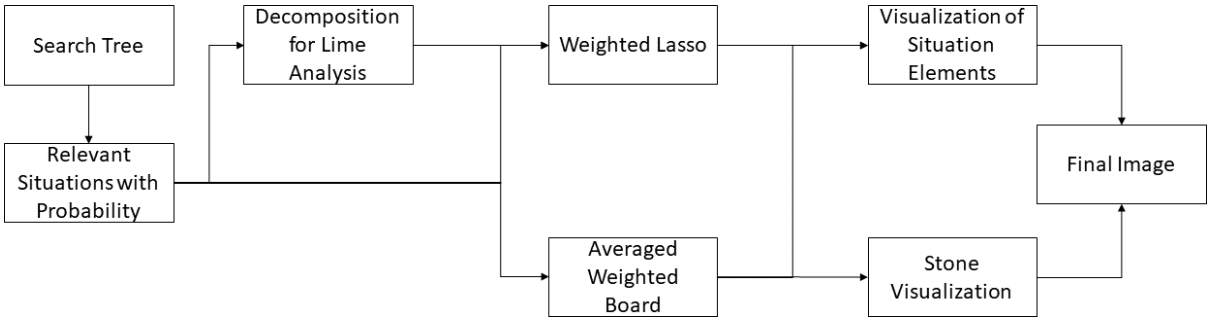


Figure 2: The data flow of the static analysis.

4. Results

This section discusses some game situations of Connect-Four and shows how the interpretation results are visualized. As explained in the previous two sections, we have a dynamic and static analysis. The dynamic analysis focuses on the potential development of the current game situation. The static analysis shows how the different situation elements contribute to the overall evaluation of the situation.

We begin the discussion with the dynamic analysis. Fig. 3 shows the game layout with the board game itself on the left side and the decision tree visualization on the right side. The picture shows the decision tree in the case of the dynamic analysis. We apply the dynamic analysis before we make a move. The tree's root node represents the game situation before the move is made. In the shown picture, we have already selected a very late leaf. One can see this at the small square on the lower right branch. Next, we display the q-values and the current value of the situation. The q-values are the values from the corresponding move of the slot. They represent the expected outcome of the game if the corresponding move is made. The value of the situation is the maximum of the q-values as the player is likely to pick the best of all options. We print all values in the current player's color, which is yellow in this case. The probability of the move to be picked is shown in the line below. The probabilities are generated by the policy of the Alpha zero algorithm. The option with the highest probability is written in green, the others in red. The color of the graph node visualizes the player that is taking turns at that point. The line thickness between nodes visualizes the transition probabilities. The user can pick different nodes in the graph to see how the AI judges the most likely development of the situation.

Fig. 4 shows the static analysis, which does not use the right pane. The static analysis contains stone positions that are already placed and positions that are likely to be placed in the future. We render a white dot into the center of stones that are likely to appear at this position in the future. The more likely it is, the more saturated the color. We derive the likelihood of stone positions from the search tree. Red and green rings around the stones visualize the contribution to the overall situation. Green means that it contributes positively to the situation, and red negatively. The color is determined by the computed coefficients of the Lasso analysis explained in section 3.

Fig. 3 and 4 show the same situation. The first figure is the dynamic, and the second figure is the static analysis. Here one can see the correspondence of the late dynamic situation with the future stones in the static analysis. We selected a relatively late move in the dynamic analysis, as indicated by the small square in the middle leaf. Suppose one analyzes the single moves made along the way more precisely. In that case, one will find that the intensity of the uncertain stones' saturation in fig. 4 decreases the further one goes into the future. Naturally, the certainty of the prediction decreases the further one goes into the future. The static analysis shows a gap between the existing yellow and potential future blue stone on the right side. This probably yellow stone in between is not included in the visualization of fig. 4 because it does not contribute to evaluating the situation. As this is an early stage of the game, naturally, all own stones contribute positively to the situation and all opponent stones negatively. Both fig. 4 and 3 show the value of the situation on top of the board. They differ because, in the dynamic analysis (fig. 3), the value is derived from the situation flagged with the box in the tree and all following potential situations. The static analysis estimation (fig. 4) refers to the game situation marked as the second node from the root in the dynamic analysis. In consequence, it covers more situations and information.

Fig. 5 shows a static analysis of the same game in one of its early stages (fig. 5a) and near the very end of the game (fig. 5b). In the situation depicted in fig. 5bit is blues turn to drop the next stone. Wherever blue will go, yellow will in the next move. This move is flagged by marking the potential blue stones in the empty slots with a green circle. Even if this is an opponent stone, the future placement is flagged as something positive as this is a prerequisite for yellow to finish the game with a winning move. The two central yellow stones are marked with the light green circle in fig. 5b are both parts of one of the potential winning constellations of connected four yellow stones that may arise from the current situation. Those same stones are already marked in the early-stage analysis in fig. 5a. However, the yellow stone in the bottom center has lost its strategic value over time. The loss of strategic value is visible if we compare the saturation of the green between fig. 5a and fig. 5b.

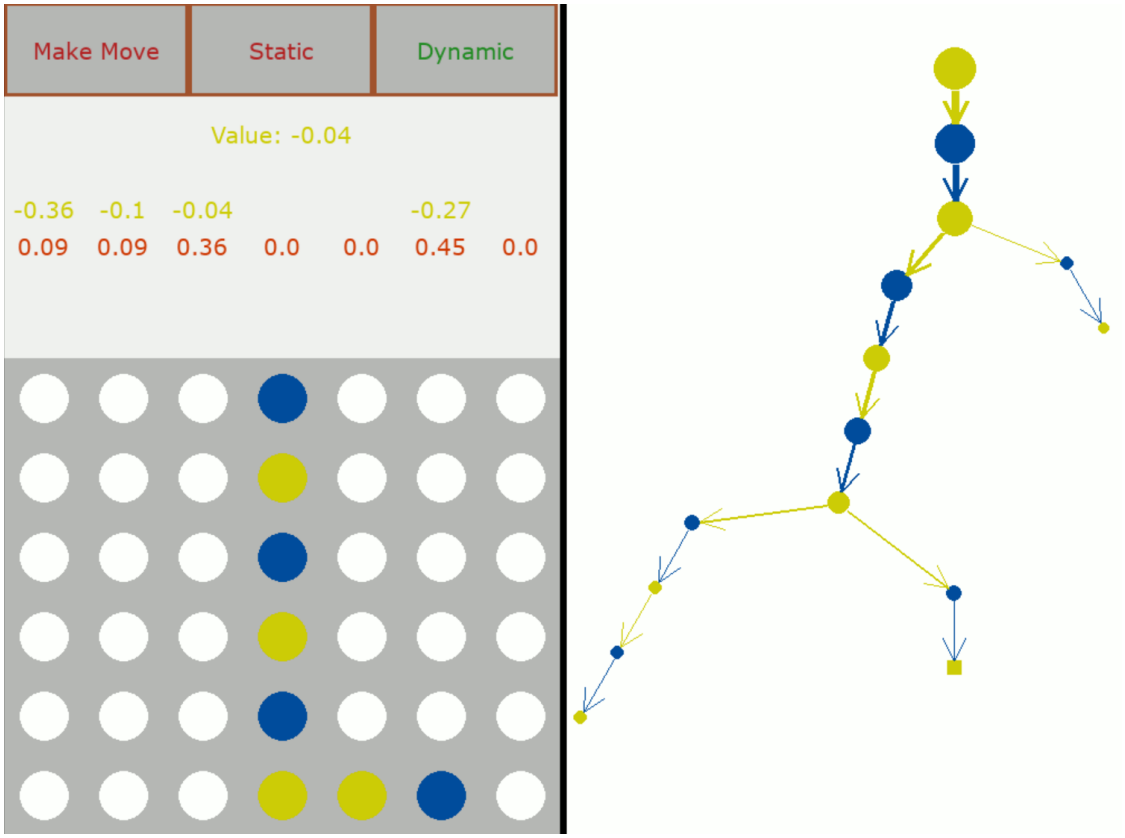


Figure 3: The dynamic analysis of the initial moves. The image corresponds to the static analysis shown in fig. 4

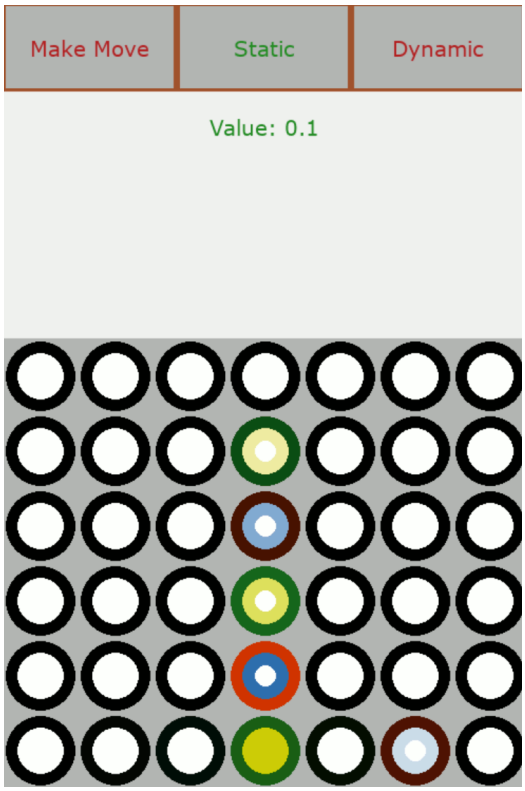
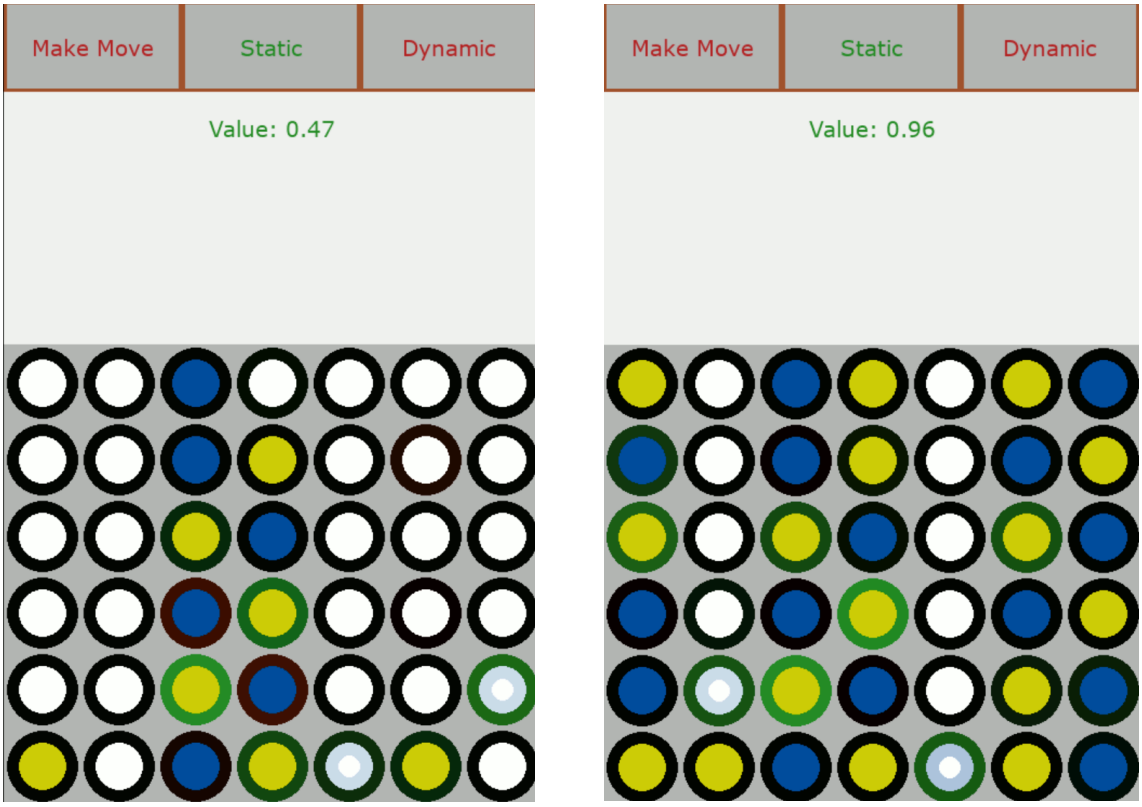


Figure 4: The static analysis of the initial move. The image corresponds to the dynamic analysis shown in fig.3



(a) Static analysis at the beginning

(b): Static analysis at the end

Figure 5: Static analysis

5. Discussion and Future Work

In this paper, we have shown how to implement an explanation technique for a board game so that a player can learn something about the game and the applied AI Alpha-Zero. The explanation technique contains a static and dynamic analysis. We have shown that a static and a dynamic analysis complement each other. Both systems derive information from the neuronal net and the search tree. The dynamic analysis is based on the search tree and the static more on the neuronal nets. The focus of this paper is the static analysis. We made Lime practically applicable to the Alpha-Zero AI by constructing a weighted Lasso analysis of the current probable future situations. This variation of Lime enables us for efficient calculation on the GPU (graphics processing unit) and meaningful visualization of the current situation.

xAI (explainable artificial intelligence) also incorporates visualization, computer-human interfaces, and domain-specific knowledge. With this respect, games in general and board games specifically are a convenient domain for experimentation. Games have a limited knowledge domain and are easy to understand by most people. Understandability is a significant advantage over application domains like medical and engineering subjects that require the cooperation of a domain expert. As the next step, we apply the general approach to the game of Othello. Othello is a relatively easy game to understand but has, compared to board games, few active players. Consequently, we only have a slight variance in the test group that we will use for user testing.

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Using Mathematics Game-based Intervention on Children with Special Educational Needs: Preliminary Findings

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Abstract: Many video games incorporate positive learning principles, stimulating students' cognitive functioning and promoting problem-solving and spatial abilities. The high levels of engagement and involvement that some students can achieve with video games are notable. Hence, video games for children with a long history of school failure, such as children with special educational needs (SEN). Moreover, it may give educators immediate and ongoing assessment of students' progress. When complemented with human tutoring, video games as a game-based intervention may improve mathematics performance since instruction is more effective when adapted to students' learning needs and pace. As part of the research project "GBl4deaf – Game-based Learning for Deaf Students (PTDC/COM-CSS/32022/2017), the video game "Space adventure: Defend the planet!" was designed to stimulate arithmetic competencies in deaf and hearing children. The player must use elementary arithmetical and spatial concepts to rebuild an abandoned space station. Each challenge has three difficulty levels. In the game challenge used in this study, the player must add or remove particles to collect resources. The current research focuses on two questions: The study follows two research questions: Q1: Did the students make any progress in mathematics achievement after playing the video game?; Q2: Is the gameplay of Space adventure: Defend the planet! an engaging experience for players? A pre-and post-game mathematical test was applied to measure mathematics achievement and an observational grid to gather information about arithmetical procedures. Ten fourth- to ninth-graders participated in the study - four girls and six boys, aged between 9 and 16, three deaf and seven hearing students with different special needs (dyscalculia, cognitive deficits, autism spectrum disorder, deafness and Asperger syndrome). Due to the COVID-19 pandemic lockdown, children played the video game using Zoom video conference software in 8-12 sessions (50 minutes, two a three times/week). The results show 4% to 19% of mathematics progression after children played the video game and indicate that they maintain the use of counting-based procedures throughout the game sessions. For instance, they kept counting both addends starting from 1 or counting by 1, 2, 5 or 10 using a number line. The current data suggest that the videogame "Space adventure: Defend the planet!" allows educators to gather immediate information about students' difficulties and progression.

Keywords. Mathematics game-based intervention, special educational needs, arithmetic competencies.

1. Introduction

Mathematics is one of the key competencies of the 2030 OECD project, and personalised learning is one of the 2030-project visions of the 21st Century.

Most researchers focus on elementary numerical competencies to design effective interventions (Marcelino, Cunha Teixeira, and Rato, 2017). Studies show that basic arithmetic is a good predictor of later school mathematics achievement (e.g. Marcelino, de Sousa, and Lopes, 2017; Hornung, Schiltz, Brunner, and Martin, 2014). Improving numeracy will lead to better individual perspectives and substantially impact society (OECD, 2018), especially with lower-achieving learners, such as children with special needs.

Systematic literature reviews found that Deaf and Hard of Hearing (DHH) children have lower mathematics achievement than hearing students. Deaf children have more difficulties in abstract counting and symbolic addition and subtraction tasks (Gottardis, Nunes, and Lunt, 2011; Marcelino, Sousa, and Costa, 2019).

Computer-based intervention (a video game) positively affects learners' motivation (Gee, 2007; Kadosh and Dowker, 2013). In good game-based learning (GBL) approaches, players and students are more willing to be engaged and immersed in an activity (Habgood and Ainsworth; Ke, 2017). Moreover, video games can create meaningful learning experiences with immediate and concrete feedback and optimal levels of challenge and frustration where a failure is a motivational tool (Gee, 2007; Granic, Lobel, and Engels, 2014). Game-based learning approaches reveal a significant and positive influence in several areas of cognition (Bisoglio, Michales, Mervis, and Ashinoff, 2014), resulting in improved performance in several areas of knowledge, such as mathematics.

Chodura, Kuhn and Holling (2015) show that intervention effectiveness is associated with direct or assisted instructions regardless of learning age but reported no significant differences between computer-based and face-to-face intervention. This lack of substantial differences means that computer-based intervention can be as effective as a non-computer-based intervention with human tutors.

The duration of the intervention is one crucial variable in applying for intervention programmes. According to Kroesbergen and van Luit (2003), shorter intervention is more efficient than 12 months. The intervention approaches are considered more effective when adaptive to the child's learning needs and pace (Burns, Codding, Boice, and Lukito, 2010; Kohn, Rauscher, Kucian, Käser, Wyschkon, Esser, and von Aster, 2020).

Concerning intervention approaches, there is a lack of studies that compares the impact of computer-based and non-computer-based intervention in basic arithmetic. The thirty-five studies analysed in Chodura et al. (2015) meta-analysis do not include a mix of the two types of intervention. An intervention with human tutors plus a computer-based intervention with personalised learning may allow lower achieving learners to go further than low achievement.

The current study is under the GBL4deaf – Game-based Learning for Deaf Students project [PTDC/COM-CSS/32022/2017] using a GBL framework where a video game was designed and developed from scratch. The project aimed to evaluate the use of an educational video game for mathematical learning (basic arithmetic and basic geometry), in particular, for deaf students.

The present work explores the effectiveness of a computer-based intervention (a video game) integrating the intervention with tutors (personalised training) to promote basic arithmetic and geometry (e.g. calculation with angles) in children with special needs. The main goal is to design an effective game intervention to promote mathematics learning and engagement in children with or without special needs, particularly deaf children.
The study follows two research questions: Q1: Did the students make any progress in mathematics achievement after playing the video game?; Q2: Is the gameplay of Space adventure: Defend the planet! an engaging experience for players?

2. Method

2.1 Participants

A convenient sample of children with different special needs, aged 9 to 16, attended public schools Grade 5-9, with a mean age of 12.5 years old - except one deaf student with a home-schooled education equivalent to Grade 4. The sample comprised three deaf students, six hearing students integrated into the Special Education program, and one girl with dyscalculia.

Table 1: Participants' characterisation

	Sex	Age	Grade	Special Needs
Subject 1	M	9	4 (home education)	Deaf without CI
Subject 2	F	12	6	Dyscalculia
Subject 3	F	16	9	Deaf with CI
Subject 4	F	16	8	Deaf with CI
Subject 5	M	13	5	Autism Spectrum Disorder
Subject 6	M	10	5	Asperger Syndrome
Subject 6	M	12	5	Cognitive Deficit
Subject 8	M	10	5	Cognitive Deficit
Subject 9	F	14	7	Cognitive Deficit
Subject 10	F	13	6	Cognitive Deficit

Note. M = Masculine, F = Feminine, CI = Cochlear Implant.

2.2 Materials

Video game "Space adventure: Defend the planet!". The software used in the present study is a delta version of a standalone game produced with the Unity game engine. The game is a mathematical educational game for formal and informal learning. The player must use mathematical abilities to solve challenging puzzles to build a space base, but only three challenges are under study in the present study. Each challenge has three difficulty levels designed to provide the player with progressively advanced mathematical knowledge and reward them with the resources necessary to build and upgrade their space base. Challenge 1 consists of an addition and

subtraction puzzle in which the player must add or remove particles of an 'atom' to create a resource. Challenge 2 consists of multiplication and division tasks in which the player must decide the number of cars needed to transport the produced gears. Still, they must determine the total amount for each round by using multiplication reasoning. In challenge 3, the player applied algorithmic thinking, mental rotation and notions of angles. It includes angles calculation and rotations in a type of game known as turtle geometry to complete a plan in a 5 x 5 grid using step-by-step instructions: turn to the right, turn to the left, step forward. The video game is research-based. The detailed information on the research design and game user research could be consulted by Costa and Marcelino (2020). The complete version of the game is open-sourced ("Space adventure: Defend the planet", 2021).

Emotional questionnaire. The questionnaire is a researcher-based scale about the PANAS - Positive and Negative Affect Schedule short-version (Watson, Clark, and Tellegen (1988) that evaluates the intensity of emotions felt by the players while playing the video game. Five positive emotions were measured: satisfied, relaxed, involved, enthusiastic and excited; and five negative emotions: confused, bored, agitated, unsatisfied, and disappointed. Players were asked to answer a 5-point Likert scale (1 = not at all; 2= a little; 3 = moderately; 4= quite a bit; 5= extremely) to the following statement: "How did you feel while playing the video game?".

Game Mathematics Contents Evaluation (GMC). GMC is a researcher-based measure in reference to The 15 Minute Norm-Referenced Mathematics Test (Chinn, 2017) in his book "More Trouble with Maths: A complete manual to identifying and diagnosing mathematical difficulties". The measure was constructed to allow the subject to demonstrate procedural (and conceptual) knowledge without verbal stimuli. For a better adaptation to the mathematical contents of the video game, 28 items were selected and 16 of the original test were eliminated. The sixteen items deleted were related to algebra, fractions and basic arithmetic operations in vertical representation. Eleven items have been added to include the mathematical contents present in the video game. The final GMC comprises 38 items related to basic arithmetic and basic geometry.

2.3 Procedure

Due to the pandemic, the video game intervention to measure mathematics achievement with an initial sample of 28 deaf students was impossible to conduct; instead, a convenience sample with children aged 9 to 14 comprised deaf students (n= 3) and hearing students. Some participants integrated into the Special Education program (n= 7) with special needs. The video game was used to support mathematics teaching and learning, such as the four arithmetical operations and Basic Geometry – calculation of angles and essential algorithmic thinking (the turtle game).

The children's online intervention took place two or three times per week with sessions of 50 min in their home environment or school. The number of desirable sessions was 12; in practice, children participated between 6 to 12 weeks.

The game sessions include the children, the tutor (a psychologist researcher), a special education teacher and the sign language interpreter (in the case of deaf children without cochlear implants).

At the beginning (moment 1-M1), middle (moment 2-M2), and end of the sessions (moment 3-M3), children were asked to fill an emotional questionnaire to gather information about how they felt after playing the video game.

Mathematics achievement was evaluated before and after the game-training sessions (measured by GMC). All the intervention sessions were recorded as a complement to observation.

3. Results and Discussion

The results show 4% to 20% of mathematics progress (Figure 1). A twelve-year-old student with dyscalculia improved by 20% (Case 2). A sixteen-year-old deaf student improved her math performance by 15% (Case 3). A 10-year-old deaf boy, a home-schooled student, finished the game in eight sessions and improved math performance by 11% (Case 1)

One student (10 years) diagnosed with mild cognitive impairment improved 8% after twelve sessions (Case 8). A ten-year-old student with Asperger's progressed by 4 % (Case 6). Five students – one deaf (Case 4), a boy with

Autistic Spectrum Disorder (Case 5), and three with mild cognitive impairment did not improve after the intervention (Case 7, 9 and 10).

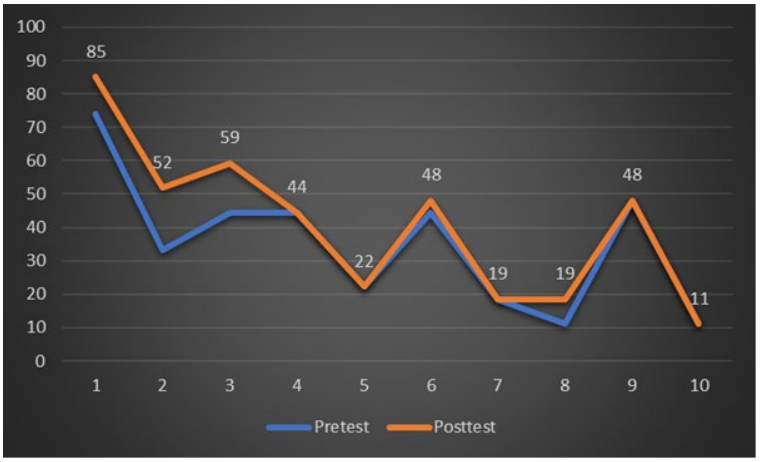


Figure 1: Mathematics Evaluation score (%) by participants before and after playing the video game

Concerning the video game as an engaging experience for players, the Special educational teachers enhanced children's motivation to play. They corroborated the results of the emotional scale applied at the beginning (Moment 1), middle (Moment 2), and end (Moment 3) of game sessions. The children felt "very" satisfied in the three moments and were willing to continue the game sessions. Moreover, all children reported feeling more positive emotions than negative ones, like feeling satisfaction, enthusiasm or being involved in game sessions.

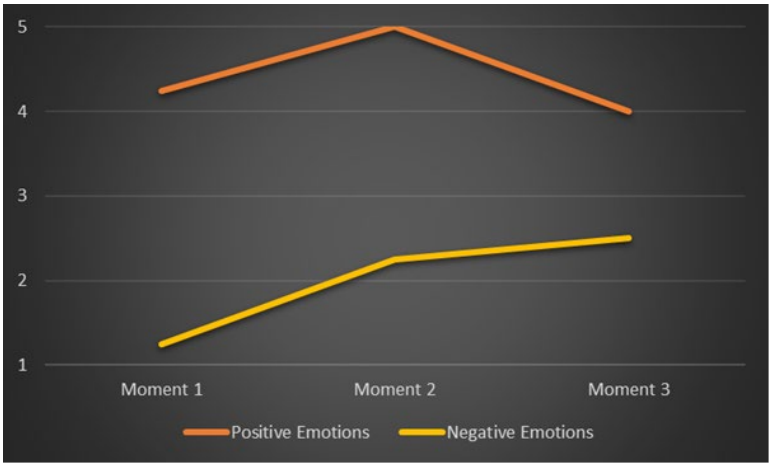


Figure 2: Positive and negative emotions reported by children at the beginning (Moment 1), middle (Moment 2) and the end of the game sessions (Moment 3). 1 = not at all; 5=extremely

The intervention results show that the video game boosts student motivation. Besides, it is a pedagogical resource that allows active learning in distance learning.

The current results suggest that the video game "Space adventure: Defend the planet!" allows educators to gather immediate information about students' difficulties and progression. Therefore, the video game was a good tool for identifying students' problems in elementary mathematics, particularly in children and young people with special educational needs. For instance, the evaluators observed that children maintain the use of counting-based procedures throughout the game sessions. Observing the mathematics behaviour while playing the game, it was possible to see that they kept counting both addends starting from 1 or counting by 1, 2, 5 or 10 using a number line instead of using no counting procedures such as compensation.

Data show slight differences before and after playing the videogame in children with cognitive deficits. The conditions of evaluation and intervention, for instance, the instrument, individual differences, family versus remote sessions, the learning pace of each child, and the number of game sessions, might explain the results.

More qualitative and ecological analysis plus additional studies are necessary to consider the video game as an effective tool to improve mathematics achievement in children with special needs. For instance, change the observational grid to include the children's game challenge strategies in the recorded game sessions.

While the video game shows potential in children's engagement and mathematics learning, the diversity of our sample requires complementary tangible resources outside the game, developed for each type of special needs, which should be considered in future work.

The study enlightens the importance of adjusting the mathematics game-based intervention approach to the child's learning needs and pace to promote mathematics achievement as a final consideration.

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Investigating Social Media Potential for Supporting Teachers' Digital Games Literacy

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Abstract: Digital games have the potential to address a variety of pedagogical objectives across a range of subject areas in education and research shows that teachers are interested to learn about the use of games in teaching. However, due to the lack of professional development opportunities, teachers typically learn about the use of games informally from their peers and on social media. This raises questions about the kind of knowledge that social media resources may be catering to teachers and their relevance for more formalized ways of game literacy development. Further, the reason for the lack of professional development options could be that research is lagging behind in testing and developing systemic models that frame teachers' knowledge of game-based learning such as the recently proposed Game Literacy for Teacher Education (GLTE) framework. To address the research gap, we investigate the following question: How do social media resources address key literacy areas of the Game Literacy for Teacher Education framework? The study tests the GLTE framework to investigate the research question. Data has been collected between autumn 2021 to spring 2022 from YouTube, Twitch, and Twitter using 1) search words in English, German and Swedish, 2) built-in recommendations and discovery functions, and 3) following links and references. Data relevant to supporting teachers in Digital Game-based Learning (DGBL) at primary and secondary levels in education were included, and 150 multimedia resources were selected for further analysis. Data were deductively coded onto the broad categories of the GLTE framework and descriptive coding was used to explore new categories. Findings show that DGBL resources shared on social media address the key literacy areas of the GLTE framework at least partially while also indicating that conceptualisations of games literacy for teachers need to go beyond technological and pedagogical integration and consider the broader societal role of games and gaming. Based on the findings we propose that game literacy for teachers is conceptualised from a broader social-cultural, critical perspective, and we suggest an updated model and recommendations for future research.

Keywords: games literacy, K-12 education, teacher games literacy, social media, informal learning

1. Introduction

Digital games have the potential to address a variety of pedagogical objectives across a range of subject areas in education (Hainey et al, 2016) and teachers indicate an interest in learning about how to use games in their teaching (Takeuchi & Vaala 2014; Máthé, Verhagen & Wiklund 2019). At the same time, there is a lack of professional development opportunities, which could be due to that research is lagging behind to develop and test systemic models that could frame teachers' knowledge and guide professional development programs in game-based learning (Foster & Shah 2019). The recently proposed Games Literacy for Teacher Education (GLTE) framework attempts to address this gap (Chen et al, 2020). Based on data collected from educational stakeholders, the framework proposes five key literacy areas: practical capabilities in instructional design for game-based learning; evaluation of game-based learning; organisation and management; general basic game literacy skills; and high-level game literacy skills. The authors call for further confirmation, testing, and updating of GLTE. At the same time, teachers report that they already learn informally about the use of digital games from their peers and on social media, driven by their own interests (Máthé, Verhagen & Wiklund 2019). This raises questions about the kind of knowledge that social media resources may be catering to teachers and their relevance for more formalized ways of games literacy development. Hence, we investigate the following research question:

Research Question: How do social media resources address the key literacy areas of the Games Literacy for Teacher education (GLTE) model?

1.1 Digital literacy for teachers

Traditionally, digital literacy has been conceptualized as skills to access the internet, find, manage and edit digital information and engage with online information and communication. For teachers, this meant properly using and evaluating digital resources, tools, and services and applying these to the learning processes. (Gilster 1997). The appearance of personal mobile devices and ubiquitous access to the internet challenged this perspective as students started to learn, communicate, and participate in digital worlds within and outside school contexts

(Smahel et al, 2020). For teachers, this means, they now need critical digital literacies that consider safety, privacy, ethical issues, communication, equal access, computational thinking, data usage, and analysis abilities of media messages, thus going beyond basic technical skills, information literacy practices, and media understanding. Moreover, teachers need to recognize possibilities such as gaming and creative digital expression, which are often an essential part of students´ lives. This requires updating teachers' digital literacies (Gouseti et al, 2021).

1.2 Game literacy

Game literacy has been approached through various lenses in research. From an operational viewpoint, game literacy is the ability to access the engaging properties of games, motoric skills, cognitive processing, and rapidly scanning virtual spaces (Prensky 2001). From a cognitive standpoint, game literacy means that players understand the procedural rhetoric of games created by the designers, which requires systems-thinking, knowledge of rule systems and algorithms (Zimmerman 2008), pattern recognition, thinking about mathematical models, and seeing the world through dynamic relationships (Salen 2007). Also, literacy emerges in specific contexts intertwined with the practices of social groups and classes (Gee 2003). These social and cultural dimensions of game literacy include criticism and evaluation, knowledge about games, and the world outside the game and the game player (Apperley & Beavis 2013). Squire (2008) proposed that game literacy's essential element is the ability to participate actively, create games, and be adept at manipulating games.

For Tao (2009), game literacy also involves affective dimensions, experience, and skills. It entails a mindset and an emotional involvement, the ability to control one´s own emotions and use the game playing to enrich and develop oneself. For Klimmt (2009), game literacy includes respect for the game rules and the knowledge of how to avoid violence and addiction. An integrative view has been proposed by Bourgonjon (2014) which combines the operational, critical, and cultural dimensions. The operational dimension refers to the ability to play and design games, have the technical skills to install and launch games, navigate through a virtual world, and interpret what happens during the game. The cultural dimension refers to games as cultural artefacts, the ability to position, interpret and discuss games in the context of other media, and as a form of artistic expression in specific cultural contexts. The critical dimensions of game literacy require the knowledge that games are socially constructed, a reflective attitude on power relations, inequality, and the different and conflicting perspectives around game culture.

1.3 Game literacy for teachers

There has been less focus on teachers' game literacy in research. The Games Literacy for Teacher Education (GLTE) framework aims to address this gap. Based on empirical data from a systematic literature review, interviews and surveys with teachers, researchers, and experts in the field of educational technology and teacher education, the framework proposes five literacy areas (Chen et al. 2020). These include:

1. Instructional design: teachers´ ability to create games for learning, and design game-based curricula, activities, teaching resources, and the learning environment, which requires design thinking,
2. Evaluation: taking critical perspectives before implementing games, carefully evaluating and critiquing games, existing empirical evidence, and observing the learning process,
3. Organisation and management of GBL: implementation of GBL in the class, directing students´ focus on the learning content, managing unexpected events and requests, controlling the length of gameplay, and managing the class schedule while avoiding unnecessary delays,
4. Basic game literacy; knowledge of games, having basic technological knowledge, and being able to access, experience, and manipulate games, and
5. High-level game literacy: game-thinking, game spirit, and having a game identity.

In summary, the GLTE model integrates technological, pedagogical, and organizational aspects of teachers' game literacy and highlights the importance of the teachers´ disposition and mindset (Chen et al, 2020).

1.4 Social media for games and teacher professional learning

Social media have seen an increasing role in teachers´ professional learning (Kimmons, Rosenberg & Allman 2021). They have been used to exchange resources, build communities, and meet individual needs otherwise not met in traditional professional development settings. On social media, teachers commonly exchange resources, practices and strategies, new classroom ideas, and insider stories on how to best implement these strategies (Greenhow, Galvin & Bret Staudt Willet 2019). Teachers can manage and control their own learning, easily access resources on an as-needed base (Greenhalgh & Koehler 2017), connect with networks much

broader than in their face-to-face settings and find more contacts with teachers with similar or diverse experiences and perspectives (Trust, Krutka & Carpenter 2016).

Social media play a vital role in gaming as well. Major platforms with an immense amount of game-related content include for example Twitch which is prominently focused on gaming. Twitch features live channels that stream various games, users can participate in a live chat during video broadcasts, and the broadcasters frequently react and reply to comments and questions in real-time. Game studios use Twitch for advertising and they cooperate with top streamers with millions of followers. Twitch has been addressed in educational research regarding synchronous community building, on-stream interactivity, and gamification to improve traditional academic MOOC courses (Steinbeck, Teusner & Meinel 2021). Another social media platform with significant game content is YouTube. It is the most comprehensive online video platform worldwide where users can watch gaming content including game trailers, behind-the-scenes videos, tutorials, and walkthroughs. It is also one of the most influential channels for game marketing and hosts many gamers with a massive fan base.

On Twitter, a leading social networking and microblogging service worldwide, players can share quick updates and tidbits about games, and connect and interact with fellow players worldwide. They can post short text messages and follow other users via update feeds. Game studios also use Twitter to stay in touch with their fans.

Considering that social media are relevant for teacher professional learning as well as game content, they can provide spaces where teachers can learn about games, join relevant teacher and game-related communities, connect and exchange experiences of DGBL with peers.

2. Research strategy

The study investigates the research question using a survey research strategy and document analysis in which documents shared or referred to were treated as the primary data source. These documents may be traditional texts such as books, articles, and reports, or digital texts such as webpages, blogs or social network postings, as well as non-textual sources such as pictures or videos (Denscombe 2014; Bowen 2009). This study uses the collective term “resources” when referring to texts and online audio-visual sources. Evaluating online resources has been a central question, and judgments need to be made regarding the authoritativeness, trustworthiness, up-to-datedness, and popularity of these online resources (Denscombe 2014).

2.1 Data collection

The social media sites YouTube, Twitter, and Twitch, have been selected for this study, considering their significant public availability, game-related content, and relevance for gaming and learning. Facebook and Discord have been also considered for the study, however, relevant groups had access restrictions and required administrator approval, hence these sites did not meet the requirements for publicly available data. Instagram and Twitter are comparable in terms of allowing uploading audio-visual information, using limited amount of texts, and following hashtags. However, on Instagram, the professional and private life of teachers are blended (Carpenter et al, 2020), while Twitter is rather used in a professional context among educators. For this reason, we omitted Instagram in favour of Twitter (Carpenter et al, 2019).

Data was collected between the autumn of 2021 and the spring of 2022 in several iterations by 1) using search words in English, German, and Swedish, 2) using inbuilt recommendation and discovery functions, and 3) following hyperlinks and references. Hence the search strategy combined researcher-defined manual search with algorithmic solutions of the platforms. Forward and backward snowballing and pearl-growing search methods were used by following hyperlinks, hashtags, and recommendations. The predefined search words included words and phrases such as “game-based learning,” “games”; “education”; “teaching with games; “games in school,” and “games in teaching” in the targeted languages.

The data collection was conducted using Mozilla Firefox and the Container extension, preventing cross-referencing. The search process started by reviewing the platform-specific search and discovery tools. Then the researcher initiated the investigation on the platforms with the pre-defined terms and investigated the search results for inclusion. Data were included if they addressed digital game-based teaching and learning relevant for primary and secondary education levels, were publicly available, and corresponded with our ethical considerations. Analog games were not considered for this study, and data older than ten years and data with broken hyperlinks or lacking information on their publisher were excluded. Data that matched the criteria were saved using the social bookmarking service Pocket. The data collection was carried out within the time limit of

the study until the search did not reveal any interesting findings. When relevant, the researcher investigated the source of the data. For example, documents or videos shared on social media were traced back to their sources when possible, such as the publishing organization's websites. Finally, data were organised for analysis in a spreadsheet that contains a unique identifier and a link to the online location of the resources. Altogether 150 resources were selected for inclusion in the final dataset, including textual and non-textual material.

3. Ethical considerations

This study follows the guidelines set by the Norwegian National Committee for Research Ethics in the Social Sciences and the Humanities (The Norwegian National Research Ethics Committees 2019). As there are no general rules, it is recommended to take a case-based approach and consider accessibility, the sensitivity of the information, the degree of interaction, and subject vulnerability (Elgesem 2016).

In this study, publicly available data has been collected from selected social media. Posts of private individuals, even if openly available, were excluded from the study. However, the study includes data from public figures who have over a thousand followers or subscribers, produce content professionally, are active regularly, and may receive financial contributions.

The sensitivity of the data was also evaluated. One issue considered was that non-text material such as images or videos should not contain sensitive information about children. Other than that, the data should consist of non-sensitive information available to the public. Data with restricted access were not collected. Furthermore, the researchers´ degree of interaction on the social media platforms was low as we did not engage in conversation or observe peoples´ behaviour online. Thus, the subjects´ vulnerability was assessed as low, as were the overall ethical risks involved in this study.

4. Data Analysis

The study uses a mixed approach to data analysis combining deductive and inductive methods and using solo coding. The process started with lean coding based on three broad categories of the GLTE framework, namely 1) practical game-based teaching (consisting of instructional design, evaluation and management), 2) basic game literacy, and 3) higher-level game literacy. Higher-level game literacy is described as the attitudes and characteristics of teachers. As this study investigated online documents, the deductive approach did not reveal information related to personal characteristics. Therefore, we used descriptive coding, also called topic tagging, as it is an approach that is well suited to analyse documents and artefacts for a detailed inventory of their content by summarising the topic of a set of qualitative data in a word or a short phrase to prepare the ground for further in-depth analysis (Saldana 2021). For example, a website about game reviews received the descriptive code “game review.” The analysis process was conducted in two phases. In phase one, emerging codes were generated from the readings of the data. The codes were added to a codebook with general code descriptions and data items were tagged and described with one or more codes. Altogether 110 codes were created. When new data suggested a new code, the code list was revisited to check for consistency. Notes were kept and developed into mind maps to visualize the emerging codes. The codes that seemed to cluster together were arranged under larger groups with descriptive topic names. In the second phase of the analysis, the topic areas were compared and contrasted to previous literacy models to verify new topics not found in the GLTE framework.

5. Findings

The search showed different stakeholders sharing resources and information relevant to game-based learning on social media, especially YouTube and Twitter. The Twitch search resulted in a few hits from direct searches, and channels were identified by following hyperlinks elsewhere. We included 150 resources shared by 30 different stakeholder groups, mainly from the US, UK, Sweden, and Germany, in 52 content areas, including 180 digital games. Findings show that various stakeholders on social media share resources that support the implementation of digital games in teaching. These stakeholders include commercial as well as non-profit organizations, multi-stakeholder federations, professional associations and public institutions such as universities, libraries, museums, organizations on the European level, and individual teachers and researchers. The resources range from simple to complex, such as a single lesson plan to more comprehensive guides and online training courses. Games or game-based learning is the full or a partial focus of the stakeholders´ activities.

The resources can be arranged into eight broad topic categories: 1) Design for DGBL; 2) Game use; 3) Games in Society; 4) Professional learning and Knowledge Sharing; 5) Research 6) Health, Wellbeing, and Safety 7) Values; and 8) Collaboration / Community (see Figure 1).

Topic 1 corresponds primarily to the Instructional Design, Management and Evaluation, and Topic 2 to Basic Game Literacy dimensions in the GLTE framework. However, we re-named these for our purposes with more illustrative names. Topics 4, 5, and 7 address to various degree, at least partially, the GLTE framework. These topic areas have overlaps and are thus not strictly separate. Nonetheless, they highlight different essential aspects of the resources. Topic 3, 6 and 8 we could not directly identify in GLTE. Below we go in more detail.

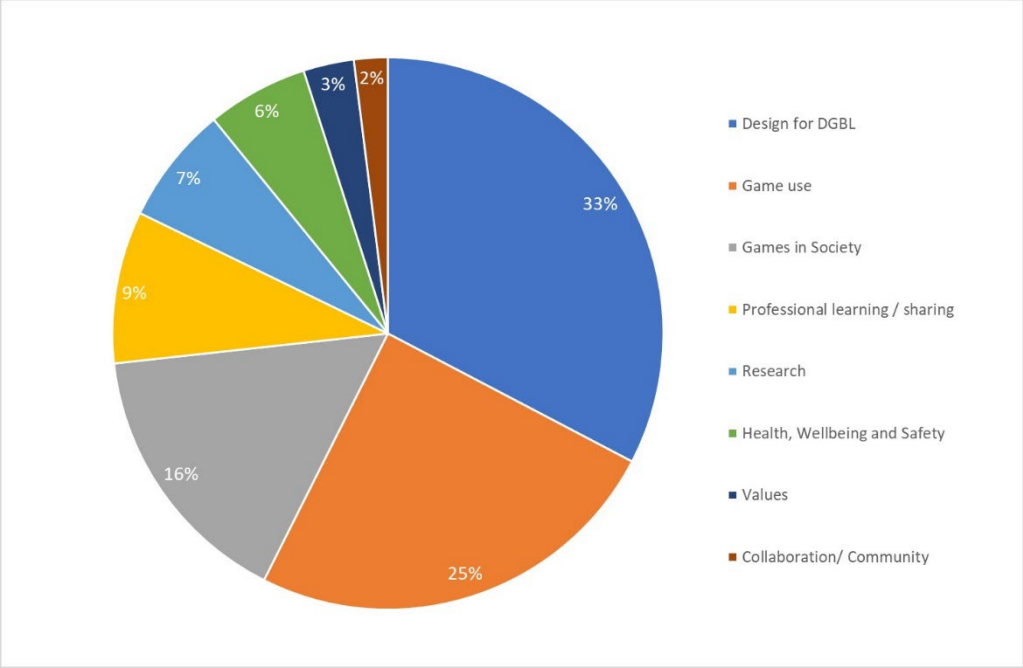


Figure 1: Distribution of topic areas in %

5.1.1 Design for DGBL

Resources that address awareness and the design of DGBL include pedagogical tips and ideas for practical implementation that teachers can adopt or redesign, including websites with lesson plans (Hey Listen Games 2021), game-based curricula (ithrive Games 2022), teacher guides (Felicia 2020) and a collection of game pedagogical ideas (Schrier 2019). Some game studios also develop lesson plans and curricula for their games (Ubisoft 2020; Epic Games 2022) or offer educational licensing and downloadable game modification ideas for educators (Positech 2016). Educational game studios typically provide curricula and lesson plan ideas for teachers combined with learning management systems to support the management and assessment of learning (Grow Planet 2020; Filament Games 2022); some provide consultancy for schools and teachers on how to build and run e-sports programs.

5.1.2 Game use

Game use resources aim to increase teachers´ awareness, understanding and use of games and support teachers to identify and select relevant games in general or according to curricular goals, subjects, and age groups. These include shorter or longer curated lists of games typically combined with game trailers, written reviews, video walkthroughs, ratings, or libraries with or without search functions (Stiftung Digitale Spielkultur 2021; Common Sense n.d.) guides on game design, and game development for teachers.

5.1.3 Games in Society

Resources that raise awareness of games as cultural-historical products understand games as a way to drive societal and digital-technological transformation and promote participation in society through digital citizenship, democracy, or civic engagement (Games for Change 2022; iCivics 2022). This topic area encompasses also participation in game culture by playing, studying, designing, and developing games. For example, youth clubs

for games as a hobby, game jams for children, or video interviews to encourage students to think about games as a field of study or as a career choice in the game and e-sports industry. Online workshops and discussion forums address the importance of a participatory game design and dialog. In summary, this topic area focuses on the wider societal role of games where games are seen not only as a teaching-learning tool but as a form of youth culture, participation, and a tool for societal transformation.

5.1.4 Professional Learning and Knowledge Sharing

Resources to support teachers learning about games in education, such as video series on programming games, MOOC on game-based learning (European Schoolnet 2019), and other types of professional development courses on game-based learning, community libraries for sharing experiences, pedagogical marketplaces, or training offerings for teachers on how to address complex topics with games. The resources include structured courses and self-reported experiences shared by game-using teachers.

5.1.5 Research

Resources with a game research perspective, for example, collections of research articles on research blogs, video recordings of discussions with game researchers, informational videos, lunchtime lessons about game-based learning, game walkthroughs, expert talk shows on the pedagogical use of games in teaching (Zentrum fur didaktische Computerspielforschung 2022) or researcher-developed educational games (USC Game Innovation Lab 2022).

5.1.6 Health and Wellbeing, Safety

Resources to support teachers in addressing health and wellness in gaming and safety during gameplay. Games are an important part of digital youth culture and participation in games should be a positive and fun experience for children. Resources focus on how to create a welcoming and inclusive game and youth culture online with an emphasis on inclusion, diversity, and equal treatment in games. Topics include digital wellbeing in gaming, programs, and resources for creating a healthy gameplay climate (Raising Good Gamers, no date), raising awareness about excess screen time, micro-documentaries for teachers on the effect of commercialisation in games (Länsstyrelsen Stockholm, no date), or video resources that address cyberbullying in games. These resources aim to raise awareness and provide practical tools to teachers to ensure positive gameplay experiences.

5.1.7 Values

Some of the resources openly articulate values to frame games and game-based learning. These embrace interest-driven learning, diversity, gender equality, fostering respect, social-emotional well-being, resilience, integration, etc. (NASEF 2022; Digital Schoolhouse 2020; ithrive Games 2022). They are commonly expressed in mission and vision statements, core values of different stakeholders or Code of conduct rules in scholastic e-sports contexts as a way to ensure that the governing values are translated into classroom gameplay.

5.1.8 Collaboration and Community

Resources that support or promote collaboration and community around games either for teachers or their students. Topics typically include school e-sports events or tournaments where students solve live challenges in teams, for example building digital Rube Goldberg machines or competing in Minecraft problem-solving challenges such as designing solutions for tackling misinformation or building various models (NASEF 2022). Teachers can either enrol their students in tournaments or re-use the ideas and create challenges for their students in the classroom. The community aspects also refer to game studios and various organizations involving teachers in communities as part of their marketing efforts and outreach programs.

6. Discussion

In this study, we investigated how social media resources address the key literacy areas of the GLTE framework based on data from Youtube, Twitch, and Twitter. The findings suggest that DGBL resources shared on social media address the literacy areas of the GLTE framework at least partially. In Figure 2, the coloured circles indicate the topic areas that align with the GLTE framework at least in part. The white circles illustrate additional topics we could not identify in GLTE.

The most commonly shared resources address the Instructional Design literacy area in GLTE which corresponds to the *Design for DGBL* topic. These focus on the pedagogical implementation of games from ideation to planning, implementation, assessment and include Organisation and Management aspects.

The second most frequently found resources address Basic games literacy dimension in GLTE including the knowledge of, access to, and manipulation of games. Resources include ideas and selection tools for finding relevant games, supporting gameplay, or aiding game development and programming. We named this topic *Game Use* in our dataset.

High-level game literacy in GLTE is one of the key areas of games literacy development described as individual traits of teachers such as open, self-generational, and creative who continuously develop their game pedagogy. As we did not investigate personality traits, we cannot confirm this aspect of the GLTE directly. However, we identified resources that may support it. For example, *Professional Learning and Knowledge Sharing* resources such as courses or shared experiences of game-using teachers can support teachers in exploring possibilities of DGBL, improve their game pedagogy, and solve emerging challenges. *Values* can frame the kind of possibilities teachers can find in GBL and influence how they integrate games and with what purpose.

Evaluation in GLTE refers to taking critical perspectives before implementing games, carefully evaluating and critiquing games, existing empirical evidence, and observing the learning process. Evaluation is addressed in *Research*, *Design for DGBL* and *Knowledge Sharing* topic areas. Empirical research results and discussions on the pedagogical use of games can support teachers to evaluate the applicability of games to their teaching. The assessment of the learning process and learning outcomes are addressed in lesson plans and game-based curricula in *Design for DGBL* and by *Sharing knowledge* and experiences.

Games in Society, *Health, Wellbeing and Safety*, *Community, and Collaboration* are aspects that we could not directly identify in GLTE. These dimensions signal the need for teachers to recognize games beyond being teaching-learning tools and acknowledge them as a form of youth culture in which students participate outside of school contexts. This calls attention to games as a social practice and the need for positive game experiences in classrooms and beyond. Awareness and knowledge about the wider societal role of games can support teachers in exploring new ways of connecting teaching with student interests, classroom learning, and outside school contexts.

An explanation for the topics not covered in the GLTE framework may lie primarily in the data collection method. The GLTE framework is based on data from educational stakeholders while data in this study reflects the agendas of a wider set of stakeholders, including the game industry, for- and non-profit organizations, pan-European stakeholders as well as teachers and researchers. These stakeholders approach games and DGBL from different perspectives reflected in the resources they create and share. Teachers need to consider the applicability of the resources created by various stakeholders, the particular values, the different educational and societal contexts, and commercial interests that impact the designs of these resources.

In summary, findings suggest that game literacy for teachers needs a broader conceptualisation than the GLTE framework suggests and thus supports the argument in research that calls for the inclusion of broader societal considerations around technology use in education and an integrated view of game literacy (Bourgonjon 2014).

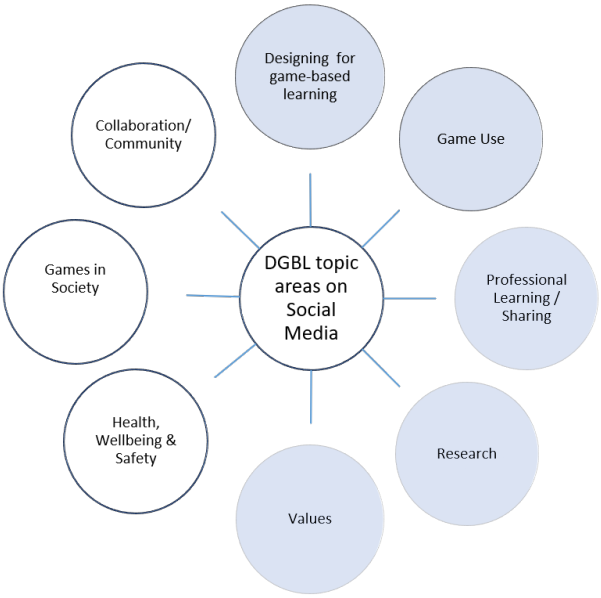


Figure 2: DGBL topic areas identified in social media resources

6.1.1 Limitations and Delimitations

Considering the time limits for the study, the search has not been fully exhaustive and offers a snapshot of resources. We checked and confirmed the validity of the data by tracing back to original publishers or sources to the extent possible within a limited timeframe. As online data may change or become unavailable, the links were checked and were still available at the time of submission. Moreover, the study did not intend to conduct an in-depth analysis. Descriptive coding is an inventory method that should be followed with a second-cycle analysis such as thematic or content analysis. The codes may not fully describe all the topics a resource addresses but rather highlight the relevant ones. Results from solo coding were validated against previous research on games and digital literacies.

6.2 Conclusion and future research

This study investigated how social media resources address the literacy areas of the Games Literacy for Teacher Education (GLTE) framework. We conclude that game literacy for teachers needs a broader conceptualisation than the GLTE framework suggests and should include the recognition of games as a form of youth culture in which students participate outside of school contexts. This calls attention to games as a social practice and the need for positive game experiences in classrooms and beyond.

The suggested dimensions reflect our dataset, and future data may require collapsing, expanding, or renaming the suggested categories. Future research could also further investigate and test the recommended dimensions or explore their use for teacher professional learning. Nevertheless, the findings indicate that conceptualisations of game literacy for teachers need to go beyond technological and pedagogical integration and consider the broader societal role of games and gaming. The resources in this study can be used as inspiration for design, critical analysis, reflection, or as practical starting points for discussions in professional development programs.

While we did not investigate the role of context in the conceptualisations of DGBL, we find indications that socio-cultural contexts play a role. For example, the competitive and community-building aspects in e-sports and digital well-being may be emphasized in some contexts. In other settings, games might be approached from the cultural-historical perspective. Yet, in another context, constructionist approaches to game-based learning, such as programming and game development, may become more pronounced. Hence, future research could investigate how social-cultural contexts influence the role of DGBL in education.

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A Digital Learning Game for Mathematics that Leads to Better Learning Outcomes for Female Students: Further Evidence

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Abstract. Stereotypes about men being better than women at mathematics appear to influence female students' interest and performance in mathematics. Given the potential motivational benefits of digital learning games, it is possible that games could help to reduce math anxiety, increase self-efficacy, and lead to better learning outcomes for female students. We are exploring this possibility in our work with Decimal Point, a digital learning game that scaffolds practice with decimal operations for 5th and 6th grade students. In several studies with various versions of the game, involving over 800 students across multiple years, we have consistently uncovered a learning advantage for female students with the game. In our most recent investigation of this gender effect, we decided to experiment with a central feature of the game: its use of prompted self-explanation to support student learning. Prior research has suggested that female students might benefit more from self-explanation than male students. In the new study, involving 214 middle school students, we compared three versions of self-explanation in the game – menu-based, scaffolded, and focused – each presenting students with a different type of prompted self-explanation after they solved problems in the game. We found that the focused approach led to more learning across all students than the menu-based approach, a result reported in an earlier paper. In the additional results reported in this paper, we again uncovered the gender effect – female students learned more from the game than male students, regardless of the version of self-explanation – and also found a trend in which female students made fewer self-explanation errors, suggesting they may have been more deliberate and thoughtful in their self-explanations. This self-explanation finding is a possible key to further investigation into how and why we see the gender effect in Decimal Point.

Keywords: Game-based learning, mathematics, gender effects, self-explanation

1. Introduction

Digital games have the potential to be powerful tools for learning, especially in the elementary and middle school years of education (Mayer, 2019). However, while there is evidence that both female and male students play digital games, they tend to prefer different kinds of games (Dindar, 2018; Phan et al., 2012). There is also evidence that female and male students *learn* differently from digital learning games. In particular, some studies have shown that digital learning games can be more effective for female students than male students in terms of learning (A. Khan et al., 2017; Nguyen et al., 2022; Tsai, 2017) and affective outcomes (Arroyo et al., 2013).

While conducting a study exploring the use of different types of prompted self-explanation in the context of a digital learning game, *Decimal Point* (McLaren et al., 2022), we also investigated whether the game led to gender differences, as found in prior studies with the game (McLaren, Farzan, et al. 2017; Nguyen et al., 2022). Prompted self-explanation is used to promote learning by encouraging students to self-explain what they are studying or how they have solved a problem (Wylie & Chi, 2014). Prompted self-explanation has proven to be one of the most robust and effective learning science principles over decades of research (Darling-Hammond et al., 2020). Our primary goal in this study was to further explore how prompted self-explanations might support learning with a digital game.

2. Gender Effects

Although female students have displayed very similar math achievement to male students in some meta-analyses (Lindberg et al., 2010), they have had worse outcomes among top performers and in advanced mathematics (Breda et al., 2018; Wai et al., 2010). Female students also generally report lower motivation, math self-efficacy, and interest than male students while learning mathematics (Ganley & Lubienski, 2016; Hill et al., 2016). Given that digital learning games often engage learners, they provide a unique opportunity to potentially increase confidence, motivation, and interest among female students in mathematics and thus better support their learning.

Despite this promise, research examining gender-based differences in learning games has been mixed. Some studies suggest that female students have better learning outcomes (A. Khan et al., 2017; Nguyen et al., 2022; Tsai, 2017) and enjoy and value learning games more than male students (Chung & Chang, 2017; Joiner et al., 2011). However, other research has found no gender differences in outcomes (Chang et al., 2014; Dorji et al.,

2015) or even an advantage for male students (Tawfik et al., 2009). Overall, relatively few studies have taken a rigorous approach (i.e., using a randomized, controlled design) to examine gender differences and learning outcomes with digital learning games. Even less research has been conducted to identify specific design elements of learning games that might lead to gender differences.

Differences in game preferences and gaming behaviors may provide clues about the underlying causes of gender differences in learning outcomes. For instance, while female and male students generally express a similar desire to play digital games (Hamari & Keronen, 2017), gender differences have emerged in preferences for game type, speed, and opportunities for social interaction (Aleksić & Ivanović, 2017; Romrell, 2014). In learning games research, one study showed that female students tend to rank goal clarity and social interaction as more important, while male students tend to place more importance on challenge, progress feedback, and competition (Dele-Ajayi et al., 2018). These preferences can produce meaningful differences in learning behaviors; for example, one study found that female students reported more positive feelings and increased help-seeking behaviors when a non-player "learning companion" was present, while male students did best without the learning companion (Arroyo et al., 2013).

Our exploration of gender differences has experimentally tested how different game features affect in-game behaviors and learning outcomes for female and male students (Nguyen et al., 2020; Richey et al., 2021). This will hopefully lead to insights as to why *Decimal Point* has led to gender effects favoring female students. This paper represents another step in that exploration by focusing on self-explanations, which have sometimes been hypothesized to support female students more than male students, based on young female students' verbal learning skills and higher quality self-explanation responses (Stevenson et al., 2009).

3. Prompted Self-Explanation

Despite contentions that prompted self-explanation within a digital learning game could disrupt game flow (Killingsworth et al., 2015), induce extraneous cognitive processing (Adams & Clark, 2014; O'Neil et al, 2014), or lead learners to quickly and shallowly respond (O'Neil et al, 2014), prompted self-explanation has been shown to support learning within games. For instance, within a middle school fractions game, O'Neil and colleagues (2014) showed that menu-based self-explanations must be carefully designed and targeted to support learning. In their game, the self-explanation prompts aimed at helping learners make connections between math and game terminology were more effective for learning than no self-explanation prompts. However, not all studies have supported the idea of incorporating self-explanations into digital learning games. In a study with *Newtonian Game Dynamics*, Adams and Clark (2014) compared menu-based self-explanation with explanatory feedback and a control condition with neither self-explanation nor explanatory feedback. They found no learning differences and, in fact, students in the menu-based self-explanation condition completed fewer game levels than the condition with no self-explanation or feedback. Thus, this study shows that including prompted self-explanation in game-based learning is not always beneficial to learning.

Wylie and Chi (2014) argue that the *type* of prompted self-explanation used in digital learning environments can explain the seemingly inconsistent learning effects of self-explanation. The authors cast the various forms of prompted self-explanation that have been used in learning technology and games along a continuum from *highly constrained* to *unconstrained* self-explanations. Some learning technology studies have shown the benefits of highly constrained self-explanations, which present the learner with a small set of options to choose from (i.e., *menu-based self-explanations,* e.g., Johnson & Mayer, 2010). Highly-constrained self-explanations create the least cognitive load for learners. *Scaffolded self-explanations* create a somewhat greater cognitive load by, for instance, prompting learners to fill in the blanks in an explanation with a set of word options. Creating even more cognitive load are *focused self-explanations*, which require learners to write their own explanations but provide guidance about what to explain, such as prompting learners to explain similarities and differences. Finally, fully unconstrained self-explanations (i.e., *open-ended self-explanations*) prompt learners to create their own explanations without guidance or focus, thus presenting the highest cognitive load to learners.

While the increase in cognitive load might seem more likely to disrupt gameplay and learning, Wylie and Chi argue that less constrained prompts facilitate more active and constructive engagement, which in turn helps learners to activate and connect prior knowledge, fill in gaps in their understanding, and ultimately achieve more robust learning outcomes. It is still unclear whether highly constrained, less demanding self-explanations, which are less disruptive to game flow but could also be answered in a shallow way, are better for learning in digital

games than unconstrained, more cognitively demanding self-explanations, which are more disruptive to game flow but could lead to more constructive engagement. We chose to study menu-based, scaffolded, and focused self-explanations in this study, sampling across the continuum from highly constrained to unconstrained self-explanations.

4. The Decimal Point Game

Decimal Point is a single-player, non-competitive game that scaffolds practice of decimal numbers and operations. The game is based on an amusement park metaphor (See Figure 1) and is targeted at middle-school students. The student moves to different theme areas (e.g., The Wild West, Jungle Land) playing a variety of mini-games (e.g., "Western Shooter," "Jungle Zipline") targeted at common decimal misconceptions. Students travel through the entire amusement park playing all of the mini-games in sequence.

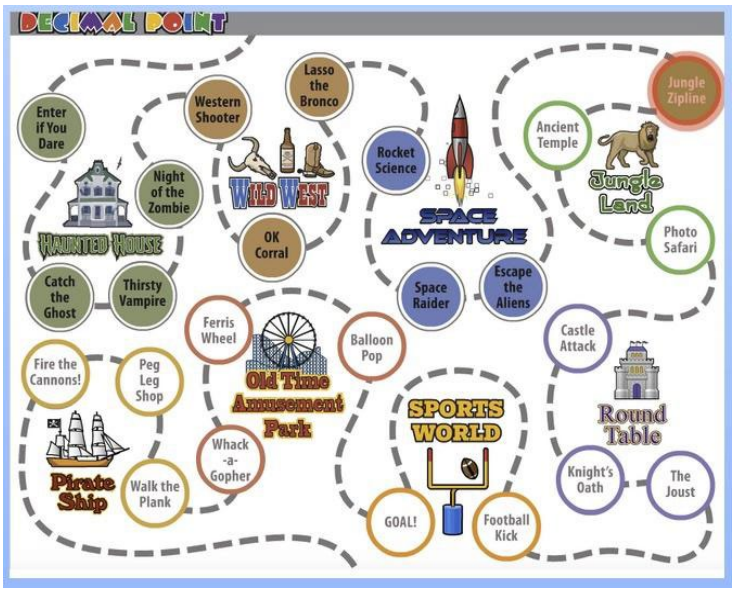


Figure 1: The *Decimal Point* Game Map

An example mini-game is "Jungle Zipline," shown in Figure 2. This game challenges the student to zipline to trees labeled with decimal numbers (e.g., 1.0111, 1.31, 1.211, 1.1) in order from largest to smallest. When the student selects a tree, the character in the mini-game ziplines to the tree and the decimal on that tree is placed at the bottom of the screen, in left-to-right order. If the learner has made any mistakes in the decimal number order after ziplining to all of the trees, they are prompted to correct their solution by dragging and dropping the numbers at the bottom to the correct position. The student continues playing the mini-game until they correctly order all four of the decimal numbers. In Figure 2, the student is exhibiting the "longer decimals are larger" misconception by incorrectly ziplining to trees in the order of 1.0111 and 1.211.

After correctly solving two problems within each mini-game, students are prompted to answer a self-explanation question, according to one of three different self-explanation conditions illustrated in Figures 3(a), 3(b), and 3(c). The prompted self-explanation questions are intended to provide a conceptual foundation to the games' problem solving. For instance, the self-explanation question of Figure 3(a) probes the misconception that longer decimals are larger by including the incorrect distractor option, "1.0111 is bigger than 1.1 because it has more digits to the right of the decimal point."

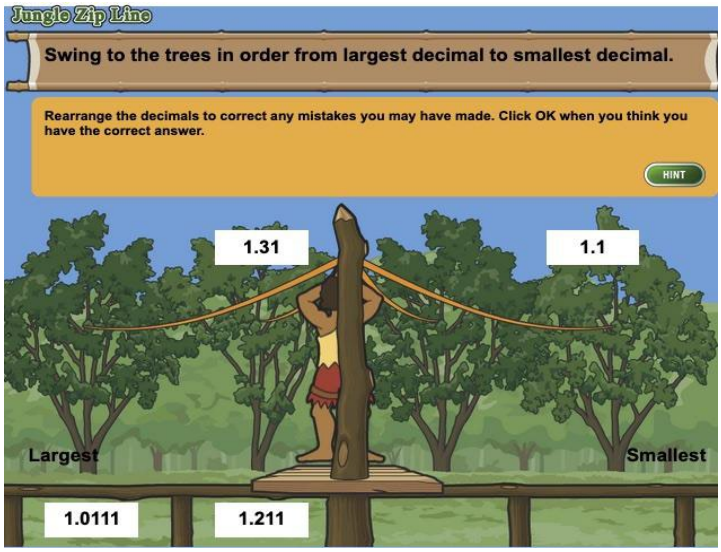


Figure 2: The "Jungle Zipline" mini-game

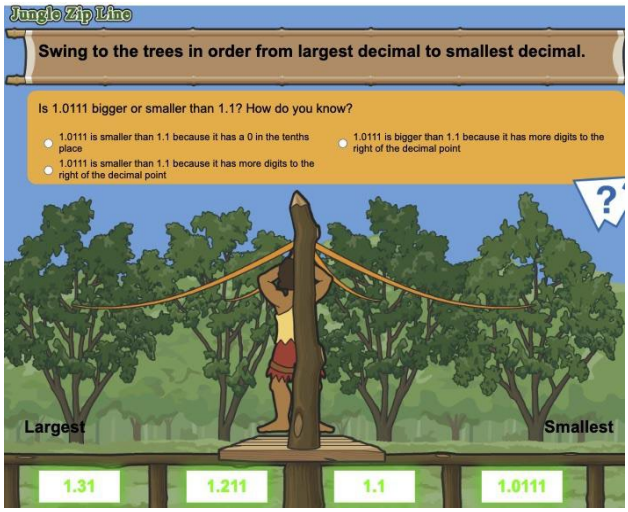


Figure 3(a): Menu-based self-explanation

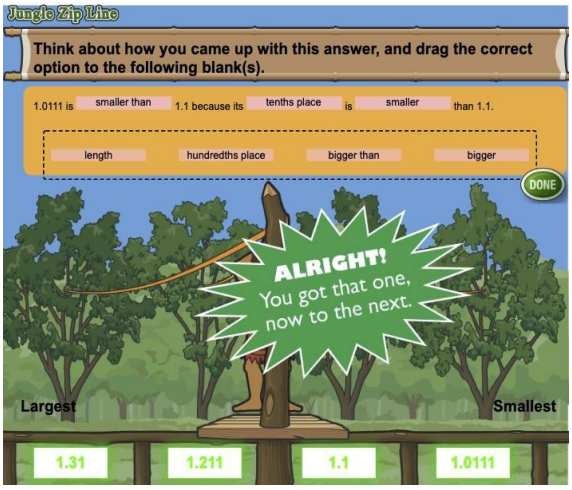


Figure 3(b): Scaffolded self-explanation

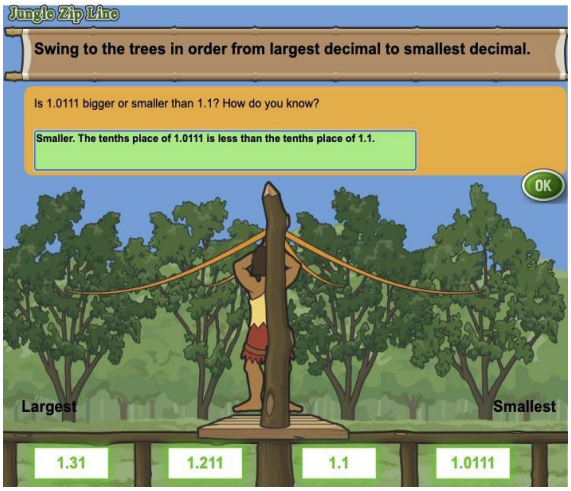


Figure 3(c): Focused self-explanation

The original version of the game employed the menu-based self-explanation approach of Figure 3(a) and led to better learning compared to a more conventional, non-game instructional technology (McLaren, Adams, et al., 2017). All studies of *Decimal Point* conducted since the initial study have employed the menu-based self-explanation approach (e.g. Hou et al., 2022; Nguyen et al., 2022), with all leading to successful learning outcomes

across conditions. In this study we explored whether other forms of prompted self-explanation sampled across the Wylie and Chi (2014) continuum might also lead to successful learning and whether male and female students differed in which prompts benefitted them the most.

The three forms of self-explanation we explored were implemented as follows:

- *Menu-based self-explanations* (Figure 3(a)): Students were presented with 3 or 4 menu options providing a conceptual explanation of the correct answer to the problem. At least one incorrect option described the misconception probed by the problem. This is a *highly constrained* approach.
- *Scaffolded self-explanations* (Figure 3(b)): Students were prompted to complete a fill-in-the-blank explanation using a word bank of 4 or 5 words or phrases. This approach most closely aligns with the scaffolded approach described by Wylie and Chi (2014) and thus is a moderately constrained approach.
- *Focused self-explanation* (Figure 3(c)): Students responded to explanation prompts about specific problems and concepts by filling in an open-text field. To assure that students would expend at least minimal effort in self-explaining, we required that their self-explanations be at least four words long and contain at least one of the words from a relevant list (including common misspellings) that would legitimately be found in a correct explanation. This approach aligns with the focused self-explanations described in Wylie and Chi (2014) and is minimally constrained.

Across all conditions, students could not proceed until they provided a correct self-explanation or, in the focused condition, an explanation that met the length and relevance requirements. To control for other differences across the prompt formats, the prompts were written to be as similar as possible across all three types of self-explanation. We chose these three forms of self-explanation to sample across the full constraint continuum while making sure to include the original menu-based approach used in previous versions of the game.

5. Research Question

In this paper we address the following research question:

> *Is there a gender effect in which female students learn more than male students from the game, and does the gender effect vary based on type of self-explanation?*

This question is motivated by the consistent gender effect that has been uncovered in prior studies with *Decimal Point,* regardless of how we have altered the game intervention (McLaren, Farzan, et al. 2017; Nguyen et al., 2022). Thus, as in these earlier studies, we hypothesized for the present study that female students would learn more than male students from playing the *Decimal Point* game. Additionally, given arguments that young female students might benefit more from self-explanation, based on their more developed verbal learning strategies and more robust self-explanation responses (Stevenson et al., 2009), we hypothesized that female students' learning advantages would be more pronounced in the less constrained self-explanation conditions, which rely more on verbal reasoning.

In an earlier paper regarding the same study reported in this paper (McLaren et al., 2022), we presented and discussed the results of other research questions pertaining to the self-explanation aspect of the study. In particular, we explored which of the forms of prompted self-explanation – menu-based, scaffolded, or focused – led to the best learning and enjoyment outcomes. We wanted to examine whether any forms of prompted self-explanation would disrupt game flow, given that engagement has been shown to explain the learning benefits of *Decimal Point* compared to a non-game equivalent (Richey et al., 2021). While we focus on the gender results in this paper, we will also summarize the previously reported results.

6. Methods and Materials

Four schools, 1 rural, 2 suburban, and 1 urban, with a total of 357 5th and 6th grade students participated in the study during regular class time. One hundred and forty-three students were dropped due to (a) failing to complete part of the learning materials or any tests or (b) having participated in a study with similar materials the previous year at one of the schools. Note that the relatively high attrition rate was due, at least in part, to running the study during the COVID-19 pandemic. Some students participated in person, some at home, and some in a hybrid format. Of the remaining 214 students, 75 were in the menu-based condition (mean age: 11.6; females: 39; males: 35; 1 did not respond), 72 were in the scaffolded condition (mean age: 11.6; females: 44; males: 28), and 67 were in the focused condition (mean age: 11.6; females: 31; males: 36)

Students completed a decimal pretest, the game intervention according to condition, an immediate posttest, a questionnaire, and a delayed posttest administered one week after the posttest. The game intervention included all 24 mini-games in *Decimal Point*, with two problems and a prompted self-explanation per mini-game. All materials were deployed using an Internet-based environment.

Students worked at their own pace during 45-to-55-minute class periods for up to a full week on the pretest, game, questionnaire, and immediate posttest. Students typically took 3 to 5 days to complete the materials. Students would log out at the end of each class and were placed in the materials wherever they previously stopped when logging back in the next time. A week after the immediate posttest, students took the delayed posttest within one 45-to-55-minute class period.

Each test consisted of 43 items, with scores across these items totaling 52 points. The test items were designed to probe for decimal misconceptions and involved the decimal skills targeted by the game, as well as conceptual questions relevant to this content. Three separate test forms that were isomorphic and positionally counterbalanced across conditions were used.

The questionnaire captured responses on a Likert scale of 1-5 from "strongly disagree" to "strongly agree" and included items from the Player Experience Inventory (PXI; Abeele et al., 2020), with 3 items each from the mastery, meaning, and challenge subscales. We also included 3 items targeting affective engagement (e.g., "I felt bored") and 3 items targeting behavioral/cognitive engagement (e.g., "I tried out my ideas to see what would happen), both from Ben-Eliyahu et al.'s (2018) Multidimensional Engagement survey. Finally, we included 5 items adapted from the enjoyment subscale of Pekrun et al.'s (2011) Achievement Emotions Questionnaire (e.g., "I looked forward to playing the game").

7. Results

First, we assessed whether student performance varied based on learning location (in person, remote, or hybrid). One-way analyses of covariance (ANCOVAs) that controlled for pretest indicated no effect of location on posttest performance, $F(3, 210) = 0.12$, $p = .89$, $\eta^2_p = .001$, or delayed posttest, $F(3, 210) = 1.87$, $p = .16$, $\eta^2_p = .017$. Thus, we did not differentiate based on location in any of our analyses. Further, a one-way analysis of variance (ANOVA) showed there were no differences in pretest performance based on condition, $F(2, 211) = 1.90$, $p = .15$, $\eta^2_p = .018$, indicating that the students across all conditions had the same level of prior knowledge.

Second, we analyzed pretest, posttest, delayed posttest, errors made in problem solving, and time spent in problem solving per condition. These results are shown in Table 1.

Table 1: The mean and standard deviation of different learning and game play metrics by condition.

* - Significant differences between conditions highlighted with boldface type and asterisk

	Menu-based (*n* = 75)	Scaffolded (*n* = 72)	Focused (*n* = 67)
Pretest	26.01 (10.47)	24.63 (10.03)	27.96 (9.69)
Posttest	30.12 (9.58)	30.58 (9.88)	33.69 (9.33)
Delayed posttest (*)	30.55 (10.29)	30.97 (10.23)	34.81 (9.88)
Problem-Solving errors	75.07 (50.52)	73.22 (46.94)	65.63 (49.67)
Minutes spent in problem solving (*)	62.65 (24.68)	83.76 (27.56)	79.12 (26.09)

In McLaren et al. (2022), we reported the results of the comparison between the three self-explanation conditions. In summary, focused self-explanations led to a better learning outcome than menu-based self-explanations on the delayed posttest, with no other significant learning differences. The menu-based condition took significantly less time in problem solving than the scaffolded and focused conditions, but there was no significant difference between conditions on the number of errors during problem solving. Although not shown in Table 1, the focused condition led to significantly greater feelings of mastery than the menu-based condition, but there were no significant differences in feelings of mastery between students in the focused condition and the scaffolded condition. Finally, there was no significant effect of condition on any other questionnaire measure, indicating that students' reported experiences of engagement, enjoyment, meaning, and challenge did not differ based on condition. See the prior paper for further details and discussion of these differences between self-explanation conditions (McLaren et al., 2022).

Next, we analyzed data to answer the research question that is the focus of the current paper: whether there were gender differences in learning with *Decimal Point*. Across all conditions, female students performed marginally worse than male students on the pretest, $F(1, 211) = 2.96$, $p = .087$, $\eta^2_p = .014$. When controlling for pretest, female students performed significantly better on both the posttest, $F(1, 210) = 8.32$, $p = .004$, $\eta^2_p = .038$, and delayed posttest, $F(1, 210) = 11.25$, $p = .001$, $\eta^2_p = .051$[1]. Thus, our hypothesis that female students would benefit more than male students from playing *Decimal Point* was confirmed.

Table 2: The mean and standard deviation of test performance by gender.

* - Significant differences between female and male students highlighted with boldface type and asterisk

	Female students *M* (*SD*) N = 114	Male students *M* (*SD*) N = 99
Pretest	24.97 (10.13)	27.34 (9.93)
Posttest (*)	31.63 (9.54)	30.94 (9.77)
Delayed posttest (*)	32.52 (10.50)	31.31 (9.97)

To determine whether the different self-explanation conditions benefited female and male students differently, we also analyzed interactions between gender and self-explanation condition. A series of ANCOVAs controlling for pretest indicated no significant gender x condition interaction predicting posttest, $F(6, 206) = 0.38$, $p = .687$, $\eta^2_p = .004$, or delayed posttest, $F(6, 206) = 1.09$, $p = .34$, $\eta^2_p = .011$. Thus, our hypothesis that the less constrained self-explanation conditions of *Decimal Point* would lead to better learning for female students (i.e., Focused > Scaffolded > Menu-based) was not confirmed.

Because we suspected that how female and male students responded to the self-explanation prompts might explain differences in learning, we also looked at self-explanation errors made and time spent in self-explanation per condition (see Table 3). Note first that the number of self-explanation errors possible per condition are on different scales. In the menu-based condition, there are 3 or 4 multiple-choice options, so students can make at most 2 or 3 errors per mini-game. In the scaffolded condition, there are several blanks to fill in so students can make a much larger number of errors per mini-game. In the focused condition, the responses were coded in a post-hoc manner, so students could make at most 1 error per mini-game.

In the menu-based condition, female students had marginally fewer self-explanation errors than male students, $F(1, 72) = 3.05$, $p = .08$, $\eta^2_p = 0.04$, but female students did not spend significantly more time in minutes than male students on the self-explanation activities, $F(1, 72) = 2.04$, $p = .16$, $\eta^2_p = 0.03$. In the scaffolded condition, female students and male students did not differ significantly in their number of errors, $F(1, 72) = 0.20$, $p = .66$, $\eta^2_p < 0.01$. Female students did not spend significantly more time than male students, $F(1, 70) = 0.20$, $p = 0.65$, $\eta^2_p < 0.01$. In the focused condition, female students made significantly fewer self-explanation errors than male students, $F(1, 65) = 4.62$, $p = .04$, $\eta^2_p = 0.07$, but female and male students did not differ in time spent on the self-explanation activities, $F(1, 65) = 0.61$, $p = .44$, $\eta^2_p < .01$.

Table 3: The mean and standard deviation of time spent and errors on the self-explanation questions. * - Significant differences between female and male students highlighted with boldface type and asterisk

	Menu-based (*n* = 74)		Scaffolded (*n* = 72)		Focused (*n* = 67)	
	Female Students (n = 39)	Male Students (n = 35)	Female Students (n = 44)	Male Students (n = 28)	Female Students (n = 31)	Male Students (n = 36)
Self-Explanation Errors	11.95 (7.89)	15.03 (7.22)	41.98 (32.00)	45.18 (25.68)	**12.90 (5.23)***	**15.58 (4.96)***
Minutes spent in self-explanation	12.49 (2.94)	11.60 (2.38)	29.65 (12.38)	28.42 (9.02)	32.32 (11.13)	35.03 (16.31)

Finally, we used a series of ANOVAs to test whether male and female students differed in their reported levels of engagement or enjoyment. Results indicated that students differed by gender only in their self-reported

[1] Note that one student in the menu-based condition did not provide gender information and was thus excluded from the gender-based analyses.

behavioral/cognitive engagement, with male students (M = 3.36, SD = .80) reporting greater engagement than female students (M = 3.07, SD = .78), $F(1, 211) = 7.08$, $p = .008$, $\eta^2_p = .032$.

8. Discussion and Conclusions

The primary finding reported in this paper is that female students learned more than male students from playing the *Decimal Point* game. They had significantly higher performance on both the posttest and delayed posttest, regardless of the self-explanation version of the game they played. This gender effect is a highly robust finding, now identified in five separate studies with *Decimal Point* (Nguyen et al., 2022), including the current one. Note that this result is not due to a ceiling effect, as the mean posttest scores were in the 30 to 33 range out of a possible high score of 52.

Why do female students consistently benefit more from the *Decimal Point* game than male students? In prior work, we suggested that *Decimal Point*, which doesn't display scores or otherwise stress math achievement or competition, may have engaged female students more than male students (McLaren, Farzan, et al., 2017). Some prior work has suggested that male students may be more engaged with achievement- and competition-oriented games (Dele-Ajayi et al., 2018). However, results from the current study indicate that male students reported greater behavioral and cognitive engagement compared to female students, despite benefitting less from the game.

Another feature of *Decimal Point* that may be behind the gender effect is the focus of the current study: self-explanation. There was no interaction between self-explanation condition and gender, indicating that different versions of prompted self-explanation did not affect students differently based on gender. This contradicts some limited prior research suggesting that female students might benefit more than male students from unconstrained prompts (i.e., the focused self-explanation), given that they may tend to write more thorough and thoughtful responses (Stevenson et al., 2009). Yet, we still suspected that female and male students interacted differently with the prompted self-explanations. In particular, we hypothesized that male students might carelessly and quickly answer the self-explanation prompts more often and thus lose the potential learning benefit of considering and struggling with the explanations for their answers. We see support for this in the menu-based and focused conditions, in which female students made fewer errors than male students. The results of Nguyen et al. (2022) are consistent with these results and also suggest that careless and/or disengaged behaviors on the self-explanation step may be the key to the learning differences between female and male students.

Looking forward, there are some exciting new directions for this research. Chief among these is an investigation of how the game not only differentially interacts with the binary gender of male and female but also how it interacts with gender typicality and gender-typed occupational interests, activities, and traits (Hyde et al., 2019). Considering gender in a deeper fashion will allow us to better understand the dimensions of gender and game features that best predict learning outcomes, how they interact, and which cognitive and affective processes mediate those effects.

More broadly, we will also seek to investigate whether our findings can be distilled as design principles and transferred to other games, and whether those games produce a similar advantage for female students. We are already engaged in a project in which we will experiment with two additional learning games, *Angle Jungle* (J. Khan et al., 2017) and *Battleship Numberline* (Lomas et al., 2013), both of which are also targeted at mathematics and for roughly the same age group. If we can successfully transfer the features from *Decimal Point* that lead to better engagement and learning outcomes to these other games, we will be on a path to better understanding how equitable learning opportunities can be provided to all learners.

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Treasure Hunt as a Method of Learning Mathematics

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Abstract: Future jobs will require students to handle interdisciplinary knowledge that goes beyond computing techniques when it comes to mathematics education. The traditional approach to education insufficiently develops the needed mathematical skills and mathematical literacy and there is a need to devise new methods of teaching and learning. We introduce game-based learning in mathematics education through carefully designed activities aiming at interdisciplinarity and increasing students' motivation, mathematical and digital literacy, physical activity, level of knowledge, etc. We propose the treasure hunt cantered around cryptography as an example activity that satisfies the described criteria. Parts of the clues leading to the treasure are hidden using different ciphers, following the historical development of cryptography. The treasure hunt is time-limited to one hour and, to successfully complete the search, students need to learn, adapt, and apply different methods of encryption and decryption. To complete the hunt in time, students must work as a team and effectively divide the tasks among themselves. Students have at their disposal all instructions and manuals in written form, and they are compelled to read with comprehension. We conducted the activity with several groups of high school students with no previous knowledge and skills in the field of cryptography. Students were asked to take a pre-test and post-test survey about their experience and familiarity with cryptography concepts. Most teams completed the search and achieved all learning outcomes. In the paper, we will describe the activity in detail, analyse the test results and give additional examples of game-based activities in mathematics education.

Keywords: game-based teaching, teaching of mathematics, treasure hunt, cryptography, literacy in STEM, digital literacy

1. Introduction

Future jobs will require students to handle interdisciplinary knowledge that goes beyond computing techniques when it comes to teaching mathematics (Staats, S. (2014)). These jobs will require lifelong learning, teamwork and applying what they learn to new situations. Most importantly, they will need to make decisions based on a quick but effective analysis of the situation and the choice of appropriate cost-effective strategies to address potential risks. Moreover, digital literacy is crucial for learning, life and work (European Commission (2016)).

Mathematics is the universal language and the foundation of education. Analytical mathematical thinking is indispensable and enables real-life problem solving in various disciplines (Haylock and Thangata (2007)).

Mathematics as a universal language describes nature, our environment and the processes that affect our daily lives. Therefore, mathematics becomes important not only for those who want to become mathematicians, mathematics teachers, physicists, engineers, etc., but it is also needed in many other fields and professions. It is no longer enough to just require students to learn mathematical content that is an integral part of the curriculum. Students are expected to acquire mathematical precision, critical and analytical thinking and reasoning, which are inherent in mathematics and are developed through mathematics education.

All this points to the need to develop students' mathematical literacy. Mathematical literacy (OECD (2022)) includes an individual's ability to recognize and understand the role that mathematics plays in the world, make well-founded decisions, and apply mathematics to everyday life needs.

Today's education faces many challenges. The traditional approach to education does not sufficiently develop the mathematical skills and mathematical literacy, therefore new methods of learning and teaching need to be developed. To develop the skills needed today, mathematics teachers should use digital technology and cross-curricular teaching in the classroom (Volk et al. (2017), Chai (2019)).

Teaching methods should put students in situations similar to the situations they will face in the future. These situations are unfamiliar and require them to test what they have learned and adapt familiar procedures and methods. To keep focus and motivation high, students must be independent and ready to adopt new concepts and procedures in a short time. To ensure effective teaching, the teacher should identify a threshold concept (i.e. a concept without which a learner cannot progress) and focus attention on the method of introducing and

adopting the concept (Meyer and Land (2003)). These threshold concepts should be part of cross-curricular topics to provide students with a fresh perspective and reinforce critical content (Kurisma and Ratinen (2021)).

With the above guidelines in mind, we present methods of game-based teaching to achieve the described goals in mathematics and other subjects.

1.1 Game-based teaching and learning

Games have been a part of the educational process since ancient times (Vankúš (2005)). In the Republic and Lows, Plato advocated the use of games in education because this is how students prepare for their future jobs. In ancient Rome, the first schools were called "ludi", meaning "games", and the aim of using games was the physical development of students.

From an early age, children learn by playing. This very effective form of teaching can be integrated into formal education. There are numerous papers describing the characteristics of game-based learning and teaching, the advantages and disadvantages, and the challenges that the teacher encounters in this type of teaching. Game-based learning and teaching uses the motivation and competition that naturally arise in play to achieve the goals and outcomes of teaching. There are numerous studies showing many positive effects of such learning (Ku et al. (2014), Vankúš (2021)) and although some of the articles report mixed results, none report a negative impact. An extensive literature review of serious games based on multiple criteria (Backlund and Hendrix (2013)) found an overwhelming amount of evidence that serious games have a positive impact on learning and motivation. The impact of serious games in mathematics education shows a significant improvement in mathematical skills in the different grades and class groups (Hieftje et al. (2017), Fraga-Varela, Vila-Couñago and Martínez-Piñeiro (2021)).

Teaching through play is certainly one of the approaches we use to develop students' mathematical literacy and create learning situations that resemble everyday situations. Students need to learn quickly and apply what they have learned, make quick decisions and devise strategies for action. The most commonly used tools for game-based learning of mathematics are computer games and board games. We distinguish between games that promote general mathematical thinking or reasoning (e.g. Chess, Trills, Sudoku, etc.) and games where mathematical tasks can be adapted to very specific domains and set for progress in the game (snakes and ladders, gallows, escape rooms, etc.).

There are examples of the implementation of game-based learning in mathematics education that take a similar approach to the one presented in this paper (Deeb and Hickey (2019), Seebauer, Jahn and Mottok (2020)), all of which report very positive results.

The hunt described in this paper was developed as part of the InAMath - An interdisciplinary approach to mathematical education project (https://inamath.uniri.hr/), a project that aims to develop and implement interdisciplinary activities in primary schools.

Now we give an interesting example of game-based learning in mathematics education. Learning definitions with understanding and operational knowledge of definitions is a challenge for students. Game-based learning is a great way to help them overcome this challenge. We suggest the game Mathematical Alias to learn definitions and apply them directly in the game. The game is easy to prepare. The teacher prepares cards with concepts that relate to a specific mathematical content. For example, if the content is geometric solids, the teacher prepares cards with concepts such as solid, cube, pyramid, side, edge, vertex, ... For younger primary students, the teacher can prepare images of geometric objects or 3D models of objects to complement the cards. A student scores points in the game if he/she explains the terms on the card to his/her partner without naming the term or similar words, or if he/she guesses the term based on his/her partner's explanation.

The cards with terms that a teacher can use in Mathematical Alias for younger primary school students can be found at https://inamath.uniri.hr/mathematical-alias/.

It is well known that using ICT as a cognitive tool in the classroom can improve educational outcomes (Jonassen and Reeves (1996)). Familiarising oneself with a programme interface can be boring for students and treasure hunt can be used to overcome this. SURFER is a free programme developed as part of the project IMAGINARY (imaginary.org) in cooperation with the Mathematisches Forschungsinstitut Oberwolfach and the Martin Luther

University Halle-Wittenberg. SURFER is a powerful cognitive tool that can be used in mathematics lessons. With SURFER, one can draw with formulas and investigate how the algebraic change of a formula infects the shape of a 3-dimensional object given with this formula.

We give an example of a hunt through which students can familiarise themselves with the SURFER interface.

- Clue1: Open SURFER, find a fruit and read the number that starts the fruit equation. Memorise this number!
- Clue2: Find one among the Fantasy Surfaces whose ordinal number is ten times greater than the number you discovered in clue 1. Do you recognise the shape? What is the value of the number for the object shown? Memorise this number!
- Clue3: Among the World Record Surfaces, find the one that looks like it is composed of two birthday caps. Set the maximum value of the number a so that the two birthday hats merge? Remember this number!
- Clue4: In SURFER you can look at every 3D object from all sides. Find an object that always looks the same from whichever side you look at it! Have you found it? What does it look like? What is it called?
- Clue5: Look at the equation of the object you discovered in clue 4. Replace all the twos with fours? What does the resulting object remind you of now?
- Clue6: Do you like games of chance? Find a mathematical object that is often used in casinos. What are the exponents of the variables x, y, z? Memorise this number!
- Clue7: Is there a universal symbol of love hidden among the drawn mathematical objects? Have you found it? What colour is it?
- Clue8: "_____ on the fire Feathers on my breath". Do you recognise the song by Massive Attack? Which word is missing? Do you see an image somewhere that reminds you of the missing word? What colour is it?
- If you answer all the questions correctly, the answers will help you draw the treasure. Draw a mathematical surface that consists of two objects (remember: we can draw two objects by multiplying their equations). One part is the shape you discovered in clue 4, let a^2 be the number you discovered in clue 6 and colour it in the colour you discovered in clue 7. The other part should be the object you discovered in clue 5, in the colour you discovered in clue 8. Set the zoom to the number you get when you subtract the numbers you discovered in clues 2 and 3 from the number in clue 1. What do you see? Now set the zoom to the number from clue 2. What do you see now? Play around a bit with the zoom slider.
- What do you get? Describe the treasure you found!

For more examples of using games in the primary classroom, see Holenko Dlab et al (2020).

2. Treasure Hunt as a Method in Mathematics education

We will pay special attention to treasure hunts as a teaching method, with a focus on mathematics education. Treasure hunts are widely used in the gamification of mathematics teaching, but the games are usually used for repetition of what has been learned. In this paper, we explain how to use a treasure hunt as a method for teaching mathematics. A carefully designed treasure hunt can create a stimulating learning environment, but it can also have several other positive effects. Treasure hunts are often organised as a team effort and thus improve students' social skills, especially collaborative learning and problem solving. It is also very easy to design a treasure hunt in such a way that it involves the physical activity of the students, if the educational environment allows for it. This has many advantages: it encourages mental activity and improves concentration and motivation. Using physical activity as often as possible in the classroom addresses the major problem of insufficient physical activity among today's children and youth (Baran et al. (2020)). Another major issue of today is digital literacy. Although people are taught from a young age how to use computers, mobile phones, tablets, etc., they often lack digital skills (van Laar et al. (2019)) in the sense that they do not know how to use the tool of information and communication technology to solve the challenges they face. The treasure hunt will be more interesting for the students and therefore it will be easier for them to achieve the intended results if they use several different methods and digital tools.

Especially in the lower primary grades, it is possible to design a treasure hunt that includes tasks from different subjects (mathematics, science, language and foreign language, physical education, computer science). We have

designed and conducted such a treasure hunt with second grade primary school students and the students' reactions were more than positive.

When a teacher introduces treasure hunts into the mathematics classroom, he or she almost inevitably applies the principles of good practise, i.e. fostering reciprocity and cooperation among students, encouraging active learning, providing immediate feedback, emphasising time on task, communicating high expectations, and respecting different talents and ways of learning (Chickering and Gamson (1991)). Students are active, engaged, interested and motivated to acquire knowledge and solve problems. The treasure hunt is a way for students to have fun and relax, it is a way for students to repeat what they have learned, but it is also a very good way to learn mathematics. The treasure hunt is also a good way to make mathematics more popular.

Moreover, the aim of the modern education system is to create, as much as possible, an educational environment in which the student is an active participant in the educational process, while the role of the teacher is more of a mentor. In addition, the new curriculum advocates an increasing collaboration between teachers and the inclusion of an interdisciplinary approach in the teaching process. There is a great need to develop activities to achieve this. The treasure hunt is certainly one of the ways to achieve interdisciplinarity. According to Bloom's Taxonomy (Bloom (1956)), there are six levels of cognitive skills: Remembering, Understanding, Applying, Analysing, Evaluating and Creating. The goal is for students to reach the level of creativity. In the following discussion, we will illustrate how to reach a higher level of taxonomy using a treasure hunt as a teaching method.

There are many challenges in designing a treasure hunt with the aim of teaching mathematics. First, a topic must be chosen that is new but not too challenging so that students can master the content. The next challenge is to present the content, which can be done either orally by the teacher or through a carefully crafted text that is available to the students throughout the treasure hunt. The written text will help to solve a major problem of today's youth, namely reading illiteracy (OECD (2022)).

The most challenging part of the preparation is the design of the tasks. It is desirable that the tasks are interesting, that they are not too easy, because otherwise they will not achieve the desired learning effect, but they must not be too challenging either, because then most students might give up solving them. If the quest is a way to teach new content in regular classes, then it is desirable that all students actively participate in it.

2.1 Secret Hunt

2.1.1 Goals

The goal of the activity is to familiarise students with the history of cryptography and the different types of encryption and to develop collaborative learning, creativity, critical thinking, the ability to cope with new situations and the independent adoption of new procedures with the aim of direct application in solving new problems, ...

2.1.2 Learning outcomes

Upon completion of the activity, students will be able to define cryptography and describe a cryptosystem based on secret key encryption, describe and distinguish encryption and decryption procedures in cryptosystems based on the Caesar's and Vigerener's ciphers, apply an attack to cryptosystems based on the Caesar cipher, apply a decryption procedure to a simple Enigma machine, use Micro:bit and mBot.

2.1.3 Description of the activity

The main topic of the hunt is cryptography, the main goal of which is to ensure secret communication between two people, commonly called Alice and Bob, in such a way that no other intruder, commonly known as Oscar, can read their messages. Encryption is the process of converting plaintext into ciphertext using a key. The reverse process, decryption, allows you to convert the encrypted text into plaintext if you have the key. The scheme of the cryptosystem is shown in Figure 1. For more information about the cryptography see Stinson (2006).

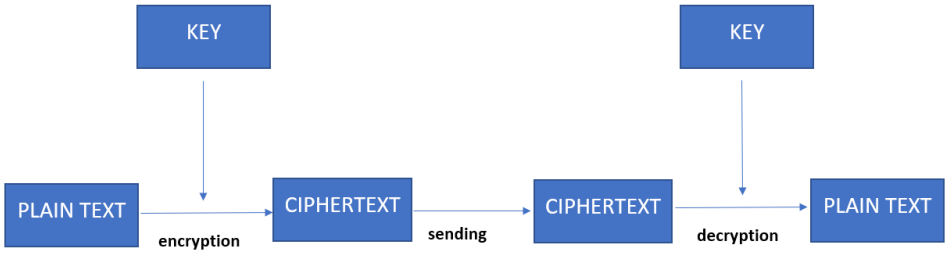


Figure 1: Cryptosystem

The hunt is designed for about 20 students, who are divided into four groups. Each group will have its own desk with all the necessary materials and a booklet with tasks and hints. The materials we have prepared for each group are:

- an Enigma machine, as shown in Figure 2,
- a set of visual cryptography transparencies (which reveal the image only when they overlap) with the following images: a flower with six petals, a happy smiley, a black circle, a 6-pointed star, the number 9 and a black square,
- a set of 5 Micro:bits prepared as follows: 4 "fake" Micro:bits which have been given a fake code (randomly decodes each letter into L, S or R) and on which 4 different stickers have to be stuck: flower with 5 petals, empty circle, a five-pointed star, a sad smiley,
- and a "real" Micro:bit that can be used as a decryption device with a black square sticker (identical to the one on the transparencies).



Figure 2: Enigma machine

At the beginning of the activity, all the devices needed for a successful hunt were displayed on the presentation table (Enigma, visual cryptography transparencies whose overlap reveals an image, two Micro:bits: one that serves as an encryption device and one that serves as a decryption device, using public key cryptography), as shown in Figure 3. Each device is accompanied by a short text containing a few sentences of general information about the device and the description of the corresponding cipher, including instructions for encryption and decryption with the obtained devices. Before the students started solving the puzzle, the team captains familiarised themselves with a short text about cryptography, its goals and uses, as well as all the devices on the presentation table and the instructions and encryption and decryption methods needed to solve the hunt.

The instructions on the presentation tables contain basic information about the Caesar cipher, the Enigma machine (definition of the key, an encryption method, a decryption method, an example), visual cryptography, basic information about public key cryptography and a brief guide to Micro:bit as an encryption or decryption device for public key cryptography.



Figure 3: Presentation desk

Each group of students is provided with a booklet containing the following clues.

- CLUE 1: Caesar encrypted an alphabet letter by replacing it with the letter 3 positions down in the alphabet. Guess a number less than 10 and discover a secret message: “YTRNRFLNSJIYMWJJSZRGJWXQCCQQC”
- EXPLANATION OF CLUE 1: This clue results in a decrypted text "TomImaginedThreeNumbersLXXLLX". The original text is encrypted using the Caesar cipher with key 5 (each letter is shifted 5 steps in alphabetical order) so that the encryption function is $e(x)=x+5 \bmod 26$, where x is the position of the letter to be encrypted, starting with position 0 for letter A. The decryption function is $d(x)=x-5 \bmod 26$, where x is the position of the letter to be decrypted.
- CLUE 2: Listen carefully to what Caesar says, lock the Enigma, and it will tell you what to do next: “OVDIDZPYOSDCYIUHTBDK”
- EXPLANATION OF CLUE 2: Students must figure out a key for the Enigma device to decrypt the message given in clue 2. As written in instructions for Enigma, key consists of a three-letter word (TOM) and the sequence of gears numbered 50, 60, 70. The previous hint gives the order of the gears: LXXLLX, i.e. 70-50-60 in Roman numerals. After decrypting the cipher text in clue 2, students discover the plain text: “TheSecretKeyIsTheNumber”.
- CLUE 3: Put the transparencies together to figure out the secret key.
- EXPLANATION OF CLUE 3: By overlapping the transparencies and finding corresponding pairs, students get the image of a flower with six petals, a happy smiley face, a black circle, a six-pointed star, a number 9, and a black square.
- CLUE 4: Transparencies help you choose the right Micro:bit. Unlock it and discover the robot's path to the treasure: “EBEJBEE”.
- EXPLANATION OF CLUE 4: Students must match the images on the transparencies and images on the Micro:bits. Only one image has a match: a black square. The message from Clue 2 is: the secret key is a number that, when combined with transparencies from the previous clue, gives a key to the Micro:bit, a number 9. Micro:bit has two buttons: A and B. On button B, the student selects a number (key): from 1 to 26. With button A, the student selects a letter to decrypt. By pressing A and B simultaneously, Micro:bit decrypts the selected letter with the selected key. Students decrypt the encrypted text of clue 4 with the Micro:bit and get the plaintext: “SRSLRSS”.
- CLUE 5: Run me and follow the path, and when the path disappears, listen to what the Micro:bit tells you (L: left, R: right, S: straight).
- EXPLANATION OF CLUE 5: Students come to the road map where the track and the mBot are prepared. The earlier clue tells them the direction to go. Following the instructions of the sequence they discovered, students should reach the target field with the message "Good job!". The message must be illuminated with a UV lamp to reveal its meaning. If students made a mistake, they should go back to the spot and find the mistake and/or start over.

All the materials one needs to implement this hunt are available at: https://inamath.uniri.hr/treasure-hunt/.

3. Methodology

This was a case study conducted with high-school students with no prior knowledge of the topic. There was no further discussion of the concepts during the lesson. We were able to conduct the activity with elementary school students, but they needed some assistance to finish the game, so we decided not to do the survey with them.

All high school students were asked to complete a questionnaire before the game about their knowledge of cryptographic concepts used in the game. We gave them a brief overview of how the game worked and then asked them to play the game, read the instructions, and learn new concepts as they progressed through the game. The game is limited to 60 minutes.

After the game, we asked participants to complete a post-test about their experience with the game. We also asked them several questions to test their understanding and practical application of the concepts and algorithms that the game was designed to teach. The goal of this survey was to measure prior knowledge, attitudes, and new knowledge and skills acquired through the proposed treasure hunt.

This secret hunt was conducted for three years with over 200 students in different settings and as an extracurricular activity. The presented survey was conducted with 64 students on a single day. The students were participants in the Open Day of the Faculty of Mathematics in year 2022.

4. Results

The survey was administered to 18 groups of students, of which 16 groups finished the hunt. Of the 64 surveys, only 52 were completed in full and only those were considered. The survey consists of 3 parts. The first part consists of 5 questions and was conducted prior to the activity (pre-test) to test students' knowledge and general familiarity with the topic.

Table 1: Students' knowledge before the activity

	Yes	No
Do you know what cryptography is about?	32	20
Have you ever heard of Caesar's cipher?	30	22
Do you know what Caesar's cipher is?	11	41
Have you ever heard of an Enigma?	48	4
Do you know how an Enigma works?	11	41

The second part consists of 2 questions and was administered after the activity to assess student attitudes.

Table 2: Student attitudes after the activity

	Yes	No
Was the activity interesting for you?	50	2
Did you learn anything new?	49	3

The third part was also conducted after the activity and includes 4 open-ended questions designed to test students' knowledge of the activity topic. Participants' answers were scored 0 for a wrong answer, 0.5 for a partially correct answer and 1 for a completely correct answer.

In the following table we report the results of the test.

Table 3: Practical demonstration of knowledge after the activity

	Level of knowledge (score)		
	Poor (0)	Satisfactory (0.5)	Excellent (1)
What is the purpose of cryptography?	16	3	33
What must two people agree on if they want to use encryption in their communication?	1	29	22
Encrypt the word “RIJEKA” with Caesar's cipher using the key 4.	5	20	27
Describe the key for the Enigma machine.	20	3	29

The average score for the third part of the survey is 0.66, which can be considered more than satisfactory.

5. Discussion

Serious games are increasingly used to teach topics that are not related to the curriculum but revolve around an interesting or important problem. Cryptography is not part of the high school mathematics curriculum, which makes this topic ideal for this survey. Many students indicate in Table 1 that they have heard of Caesar's Cipher and Enigma, but very few indicated that they knew how these systems worked before the game.

The results of the practical section in Table 3 of the survey confirm the effectiveness of the proposed model. Students showed a measurable increase in their familiarity with the terminology and ability to apply the knowledge. For example, the vast majority of students were able to encrypt the word using the Caesar cipher, but some of them shifted the letters in the opposite direction and confused the encryption and decryption procedures. Most of the student teams managed to solve the game in time without any help or interaction with the teacher, and the average test score was better than expected. We should emphasise that students had no incentive (in the form of a grade or credit) to achieve a good score on the test, which is a compelling argument for game-based learning.

The positive feedback from the participants after the treasure hunt, which you can see in Table 2, is overwhelming. They expressed their satisfaction with the topics covered and the knowledge and skills acquired.

6. Conclusions and plans for future work

The aim of this paper was to present an interesting format for teaching mathematics that allows us to introduce new concepts to high school students through a fast-paced game that allows students to learn and apply mathematics and physically interact with mechanical and digital versions of algorithms and systems. This game encourages players to try different strategies, cooperate and discover new content on their own and finally test their skills.

The survey results show a very positive response to a learning format that leads to high motivation to learn new concepts. The practical part of the survey confirmed the effectiveness of the proposed model, where students showed an impressive, measurable increase in knowledge of a complex new topic. This approach can also be applied to other areas of mathematics with different levels of difficulty.

An interesting extension of this treasure hunt would be to create an online 3D multiplayer version of the hunt where students learn, test themselves and compete with others. This would probably increase the number of players in the game but would require a thoughtful and possibly significant revision of the activities.

It would be interesting to conduct a study to investigate the impact of the proposed method on the adoption of threshold concepts and the acquisition of higher order learning outcomes. The study should identify threshold concepts in first grade high school mathematics and include an experimental and a control group of high school students. The treasure hunt should be designed for the identified concepts and conducted with an experimental group while the control group is taught in a traditional way.

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The Project Win Game™: A Serious Game for Project Management Simulation

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Abstract: Agile project management methodology usage have grown widely in the last decade. Not all types of projects should apply agile methodologies, and the tasks that would typically be executed by a project manager are not (explicitly) addressed in agile methodologies. This paper describes The Project Win Game: a serious game for people to experience the differences in decision-making between traditional/waterfall and agile projects. The game engages an audience in complex decision-making and allows them to experience the effects of their decisions; this allows non-managers to learn project management responsibilities and translate that experience into knowledge. This paper describes the gamification of project management, the development of the game, and the lessons learned through single-player and competitive play. This paper would interest people that need to engage non-managers in management tasks and understand how a board game builds knowledge based on the experience of playing the game.

Keywords: serious game, project management, gamification

1. Introduction

Agile project management methodologies have grown widely in the last decade. Project management methodologies guide development life cycles with roles, rules, events, and practices. Agile methodology success rates are on par with projects managed under a traditional methodology such as waterfall or plan-driven (Serrador and Pinto, 2015). Some of the tasks typically executed by a project manager are not (explicitly) addressed by agile methodologies. Roles such as the team members, product owner, and project sponsors assume the informal role in some project management tasks (Sutling, Mansor, Widyarto et al., 2015, Miller, 2020). Thus, there is a need to introduce project management decision-making to a diverse group of people involved in project teams.

Decision-making is an important soft skill practiced daily by project managers as they manage schedule, quality, risks, and resources. Experience is necessary to improve decision-making skills, and project performance is correlated with accumulated project experience (Rumeser and Emsley, 2019). Mismanagement is one of the reasons for project failure. Serious games are seen as a way to build practical experience by engaging in an environment that allows experimental learning (Rumeser and Emsley, 2019, von Wangenheim, Savi and Borgatto, 2013).

Serious games are "games that engage the user and contribute to the achievement of a defined purpose other than pure entertainment (whether or not the user is consciously aware of it)" (Engström and Backlund, 2021: p. 1). They offer students an opportunity for experiential learning and constructivism; experiential learning occurs through direct experience and constructivism constructs rather than acquiring knowledge. Constructivism builds skills and critical thinking through problem-solving. "Thus, a game may provide a student the opportunity to learn in a deeper, more immersive way than what is offered from a classic lecture or even more modernized instructional media." (Thornton and Francia, 2014: p. 16).

Marcelino and Domingues (2022) found 30 serious games covering project management knowledge areas from *A Guide to the Project Management Body of Knowledge* (PMBOK guide). With the emergence of agile methods, practice games are emerging, such as the distributed agile delivery (Sharma, Kaulgud and Duraisamy, 2016, Omidvarkarjan, Conrad, Herbst et al., 2020), scrum framework (von Wangenheim, Savi and Borgatto, 2013, De Souza, Seabra, Ribeiro et al., 2017), and the Kanban method (Heikkilä, Paasivaara and Lassenius, 2016).

Although serious games have been proven as a method to build project management knowledge, understanding, and gain, they are role-specific, not broad enough, or target inexperienced students. As pointed out by Omidvarkarjan, Conrad, Herbst et al. (2020), many games do not reflect real-world challenges. They have been investigated on university students with limited industry experience. Rumeser and Emsley (2019) note that project success is a broad category whose complexity is not limited to time and costs but incorporates quality

and dealing with risk, uncertainty, and scope changes. The identified studies do not cover the impacts of the methodology decision on the project outcomes, nor do they target teaching team members to fill in the gaps.

This paper describes The Project Win Game™: a serious game for people to experience the differences in decision-making between traditional/waterfall and agile methodologies. Section two provides related work. Section three describes the gamification of project management, the development of the game, and the lessons learned through single-player and competitive play. Section four includes the discussion and conclusions.

2. Literature Review

2.1 Project Management

"A project is a temporary organization to which [human, material, or financial] resources are assigned to do work to bring about beneficial change" (Turner, 2006: p. 1). "[P]roject management is the means by which the work of the resources assigned to the temporary organization is managed and controlled to deliver the beneficial change desired by the owner" (Turner, 2006: p. 93). Project management lifecycles, activities, and roles are codified in standards and guidelines, such as "ISO 21500:2012, Guidance on Project Management" (ISO, 2012), *APM Body of Knowledge 6th Edition* (APM, 2019), and the PMBOK Guide (PMI, 2021). The traditional, waterfall, and plan-driven methodologies are lifecycles with a stage-gate or phased lifecycle with an upfront plan with the time limitation and termination conditions known when the upfront plan is created. The project management activities and control are centralized in the project manager role.

Several methodologies or frameworks follow the four values and 13 principles described in the *Agile Manifesto*. The *Agile Manifesto* provides a flexible framework for managing technology projects that responds to dynamic project situations (Beck, Beedle, Bennekum et al., 2001, Serrador and Pinto, 2015). Each agile methodology has its own roles, rules, events, and practices; however, they encourage iterative and incremental development lifecycles while using self-organizing teams to evolve the product through collaboration between the development team and the client. Scrum, XP, Lean, and Kanban are the most frequently referenced agile methodologies in surveys on agile adoption and in the project management literature (Shastri, Hoda and Amor, 2016, Miller, 2020). Some project management responsibilities are inherent in the agile methods; however, there is no explicit project manager role, and project management tasks are not explicitly identified. Table 1 identifies a set of project management tasks (from the ISO standard) that are the responsibility of other project roles in agile projects, according to Miller (2020). The table identifies the shift in responsibilities from the project manager role in traditional projects to other roles in agile projects.

The importance of decision-making skills is widely accepted as needed by a project manager. "More often, projects are unsuccessful because of project managers' failure in communicating problems, working within the culture of the organization, motivating their team, managing stakeholders, understanding strategic objectives, solving issues effectively, and making the right decisions (Rumeser and Emsley, 2019: pp. 23--24). With the decentralized project management responsibilities in agile methods, team members need awareness and understanding of their responsibility in project decision-making. Moreover, there is a difference in the project management skills needed for traditional and agile projects. Furthermore, agile methods do not apply to all types of projects, such as those that require rigorous analysis for safety- and life-critical systems (Coram and Bohner, 2005, Tanner and Willingh, 2014). Thus, there is also a need for a project manager to adapt experience and knowledge when moving from managing traditional projects to managing agile projects and for non-project managers to learn about project management responsibility.

Table 1: Distribution of project management responsibilities in an Agile Project (Miller, 2020)

	Team	Product Owner	Scrum Master	Project Manager	Other
Manage stakeholders	(+)	(+)	(+)	(-)	(+)
Establish project team	(+)	(+)		(-)	(+)
Control resources		(+)	(+)	(-)	(+)
Manage project team	(+)	(+)	(+)	(-)	(+)
Develop budget		(+)		(-)	(+)
Control costs		(+)		(-)	(+)
Identify risks	(+)	(+)	(+)		
Assess, treat, and control risks		(+)	(+)		
Select suppliers		(+)			
(+) more or (-) less responsible in agile projects than traditional/waterfall projects.					

2.2 Serious games

Engström and Backlund (2021) define serious games as engaging the player in a defined purpose. They argue that the defined purpose of play makes a serious game a utility that differentiates it from games played voluntarily for enjoyment and as an unproductive activity. Thus, the authors suggest that serious game development concepts require gameplay and utility experience, where gameplay is the interaction between the player and the game world, systems, or rules.

Świerczyńska-Kaczor and Wachowicz (2013) found that gameplay is associated with increased student engagement in learning, positive emotions, and perceived effectiveness and is a useful tool for introducing managerial or economic issues to students. Games have a distinct advantage, over other learning methods, of keeping the students engaged for extended periods. They offer students an opportunity for experiential learning and constructivism, as described by Thornton and Francia (2014). Experiential learning occurs through direct experience. Constructivism builds skills and critical thinking through problem-solving by constructing rather than acquiring knowledge.

Serious games impart knowledge by "Observing the properties and behaviors of actors and objects, Understanding the relationships between actors and objects and their effects, and Performing tasks and solving problems" (Thornton and Francia, 2014: pp. 16--17). Rumeser and Emsley (2019) refer to serious games' ability to provide an environment to build hands-on experience in complex, realistic project situations. The authors point to four advantages of using serious games for building project management skills. First, players are allowed to interact with one another in decision-making. Second, there is an opportunity to introduce many situations that require decision-making and problem-solving skills. Third, serious games can simulate the pressures project managers face in the real world. Lastly, the games can develop critical thinking and reason based on reflective thinking in decision-making.

Barbosa, Pereira, Dias et al. (2014) suggest that serious games should have a main quest and a set of related learning mechanisms. The players accumulate experience and progress through the game by solving problems through the interaction with the learning mechanisms. The learning mechanisms can be quizzes, puzzles, or mini-games. Świerczyńska-Kaczor and Wachowicz (2013) explain that for a serious game to be engaging, activity design should challenge the player's skill level with progressive levels of complexity. The interactivity, aesthetics, and quality of the game design influence player satisfaction.

2.3 Related Project Management Serious Games

Based on a systematic literature review Marcelino and Domingues (2022) found 30 serious games covering project management knowledge from the PMBOK guide. They performed a content analysis and experimentation on 12 games with a demo version and documentation. They concluded that the existing serious games cover some specific project management knowledge areas and process groups, but not all. The authors did not comment on the type of methodology—traditional or agile---applied in the games.

Rumeser and Emsley (2019) combined project complexity and decision-making into a serious game. They found that serious games can improve project management decision-making. Complex games effectively improve group decision-making performance when members have at least two years of experience. The target of the game was project managers. However, the evaluation limited performance measures to time and costs and did not include risks and scope change factors.

Like project management, some games introduce agile methods or specific practices. For example, SCRUMI introduces key concepts of the Scrum framework using an electronic board game consisting of questions and answers (De Souza, Seabra, Ribeiro et al., 2017). SCRUMIA is a pencil and paper game for developing an understanding and knowledge of applying Scrum (von Wangenheim, Savi and Borgatto, 2013). The collaborative Kanban board game addressed the Kanban workflow, lean thinking, and the related measures such as work-in-progress limits, lead time, and bottlenecks (Heikkilä, Paasivaara and Lassenius, 2016).

Games for agile practices cover delivering product features, collaborative games, and efficient retrospectives. Sharma, Kaulgud and Duraisamy (2016) used a serious game to address delivering product features as fast as possible to produce the most value possible. Przybylek and Kowalski (2018) presented collaborative games for scrum meetings to improve communication, commitment, and creativity. Collaborative games are structured

techniques to encourage communication and information exchange to solve practical problems such as product feature planning or acceptance.

The games in the project management and agile domain seem narrowly focused on either project managers or team members. The cross-over of project managers to agile or non-project managers to project management is not a transparent aim of the identified games or studies.

3. The Project Win Game™

3.1 Gamification

The gamification model canvas was used to facilitate an understanding of gamification design and to design the game (Escribano and Cp, 2017). The canvas has nine sections: platform, players, components, mechanics, behaviors, aesthetics, dynamics, costs, and revenues. It was selected as it was easy for a non-expert to understand and comprehensively identify the game and business considerations. The following sections describe the game design by canvas section.

3.1.1 Platform

The platform is the medium on which the game mechanics are implemented, e.g., computer, board, and card. The Project Win Game is a board game that simulates a 33-week project to build a smartphone. A board game was chosen for the ease of incorporating the play into face-to-face business workshops and training sessions. A physical board makes it easier for team collaboration and for an instructor to observe the players and provide feedback. A smartphone was chosen as it is most likely common to all players and thus makes it easy to understand how the pieces may be constructed through a project. Alternative product developments or game modes are possible through the blank cards provided with the game.

3.1.2 Players

The players are the people or roles that are the targets in whom we want to develop behaviors. The game is designed for one to four players, and a player may be an individual or a team. The target players' profiles are project managers, team members, scrum masters, or product owners who need to gain understanding, knowledge, or experience in the project management decisions for agile projects or the difference between agile and traditional projects.

3.1.3 Components

The board game consists of the following elements or characteristics that are the game's mechanics and give feedback to the players.

- A gameboard
- Monetary chips in four denominations
- Value credit cards in three denominations
- Six types of issues and opportunity cards
- 100 blank cards
- Numbered dice
- Colored dice

Per player:

- Numbered cards for moving around the board
- Deck of 40 team member cards
- Deck of 31 product cards
- Avatar
- Notepad and a pencil

3.1.4 Mechanics

The mechanics are the rules for how the components interact to create the game dynamics.

First, the player must select a methodology used during the gameplay. This decision influences every other decision the player will make throughout the game. In competitive play, the player with the highest amount of value credits at the END wins. The timing for when value credits are accumulated is based on the methodology.

Each team member card has a cost, a work productivity production, and several personal attributes (e.g., experience, skills). Each product feature card has a work productivity requirement and a value. The player receives a monetary budget.

The player must decide the project team composition based on team member cards and the product features based on product feature cards. The work points from the team member cards determine the number of product features that can be delivered; each team member has a cost. The value credits from the product feature cards determine the number of value credits that can be collected; each product feature requires a number of work points. The goal is to deliver the highest value credits based on a given budget. At each turn, the player selects a numbered card representing time steps to traverse the board tiles. The player reacts to the tile marking, including phase or iteration changes, change requests, risks, and issues or opportunities.

In a controlled setting, such as a workshop, players' decisions can be observed, and feedback or discussion can be provided on their decisions. That and the alternative modes of play allow for complexities to be introduced into the game. For example, the game could be changed as follows.

Table 2: Alternative playing modes

Playing mode	**Additional learning**
As designed	See behaviors
Roll numbered dice to decide the number of tiles to move forward	Uncertainty in progress
One set of team member cards per two players	Resource constraints
Mandatory cards from two decks of product cards, and then one set of product cards per two players	Competition and time-to-market leadership
A single type of issue and opportunities with no color dice roll	Specific risk management
Monitoring gameplay	Team diversity, including personal attributes and supplier decisions
Use of blank cards for project-specific modifications	Project-specific cases

3.1.5 Behaviors

In Table 3, the behaviors are the project management actions for the players. Each behavior requires one or more decisions from the player related to the project management knowledge area. The learning mechanisms are the components in the game to support the learning goals.

Table 3: Behavior, decision, and learning mechanism

Behavior	**Decision**	**Learning Mechanism**	**Knowledge area**
Selecting a methodology	• Project lifecycle	Gameboard Team member cards Product feature cards Issue and opportunity cards	Integration
Building a team	Team composition • by role • by budget • by work productivity	Team member cards	Human resources
Managing the team	• Team composition by attribute	Team member cards Issue and opportunity cards	Human resources
Deciding product features	• Product design by feature by methodology constraint • Product feature by available team productivity	Product feature cards Value credit cards	Scope
Managing change	• Aspects of the plan to change	Gameboard	Integration
Budgeting a project	• Team composition by available budget • Product features team composition by budget • Team composition by duration • Budget contingency	Team member cards Monetary chips Issue & Opportunity cards	Budget
Focusing on value	• Value by Product Feature by Team composition	Product Feature Value credit cards	Value

Behavior	Decision	Learning Mechanism	Knowledge area
Dealing with issues and opportunities	• Impact of risks on team compositions, product features, and value	Issue and Opportunity cards for six frameworks: - Process - Quality - Strategy - Structure - Team & Roles - Technology Risk tiles Numbered dice for progress uncertainty	Risks

3.1.6 Aesthetics

When players interact with the game, the desirable emotional responses expected in the player are gratification, surprise, hope, or fear. The player builds a plan to achieve the project objective, and as they traverse the board, the player must act on two fronts. First is the allocation of planned expenses for the project team and the receipt of value credits based on their plan. This action offers instant gratification when they receive a benefit (value credit) for their actions. The second aspect is responding to the issue, opportunity, or risk. The fear is that a negative issue will derail their plans; the hope is that a positive opportunity will arise. The issues and opportunities can occur through risk tiles on the board or from issue and opportunity cards. Finally, the aspect is the competition between players.

3.1.7 Dynamics

The gameplay takes at least one hour. There are 20 to 30 minutes in the planning to decide the methodology, team composition, and product features. The remaining time is spent traversing the board, responding to issues and opportunities, revising the team composition, and paying the team costs.

3.1.8 Costs and Revenues

Table 4 describes the main costs of developing the game. The game is integrated into project management workshops and does not currently have stand-alone revenue projections. It is expected to replace the lecture time in the workshop with gameplay and feedback.

Table 4: Costs by development phase

Phase	Description	Costs
Initial development	Self-developed components	Less than 50 USD
Prototype #1	Ordered individual components	460 USD
Prototype #2	Prototype from game manufacturer	600 USD
Production	20-30 games from game manufactures	10,000 – 20,000 USD

3.2 Game Production

3.2.1 Content Development

The game was developed in stages. First, a prototype was created with simply designed components based on the gamification model canvas. The game board was A3-paper size, and the cards were printed from business card stock.

Next, the components and behaviors were revised, considering the input from the participants. Game components were exchanged. For example, a spinning wheel used to simulate random issues was replaced with the issue and opportunity cards. Furthermore, the board was redesigned to have a single method for introducing issues and opportunities into the game. Specifically, time tiles that required actions due to vacations or holidays were removed. Such events were included in the issues and opportunities cards. Additional issue and opportunity cases were added. The rules were revised to address the case when a player reached the END tile while other players remained on the board. Play continued until all players reached the END or were eliminated by running out of budget; this was more consistent with the real world. The gameboard was printed on A1 paper, off-the-shelf components for the avatars and dice, and the other components were ordered from multiple vendors: self-designed playing cards, square business cards for value credits, and poker chips for the money.

In the next stage, the game was constructed using more stable pieces. The issue and opportunity were made more consistent with typical project risks. A colored dice was added to add dynamics in selecting the issue and opportunity cards. The team members were further refined to remove gender and add more attributes to the face of the cards.

The current version of the game was formalized.

3.2.2 Testing and Validation

The testing and validation of the game were done through several cycles of play with different profile people. There was a feedback session after each gameplay, and adjustments were made. Table 5 shows the people included in the testing and validation stage. Figure 1 is a photograph of the game as laid out for two players.

Table 5: Test participants

Session	Game version	Participants
1	Prototype #1	Business change manager PMP, PMI-ACP, CSM Project Manager (game creator) Project Administrator (game creator)
2	Prototype #1	Project manager Agile team member Pedagogic specialist
3	Prototype #1	Traditional Project Manager Scrum Master
4	Prototype #2	PMP and Pedagogic specialist Project Administrator
5	Prototype #2	PMP, PMI-ACP, CSM Project Manager (game creator) Student
6	Prototype #2	Project Managers (alone)
7	Prototype #2	Pedagogic specialist (alone)
8	Prototype #2	Review of instructions by a gaming specialist



Figure 1: Photograph of the game laid out for two players

3.2.3 Manufacture

The criteria for selecting a game manufacturer were based on the quantity and components availability. Many manufacturers required a minimum quantity in the hundreds. Our needs were much more conservative, with a quantity in the 10s. For the diversity of components, game manufacturers that offered individual components were added to the shortlist.

From the shortlist of available game manufacturers, five were contacted. Not all manufacturers responded. Of those that did, we received estimated costs and delivery conditions according to the components we described. We specifically requested a prototype. Ultimately, a vendor was chosen that responded and could produce all the game components.

The manufacturer provided a template for each printed component. Specifically, the box, the instructions, and the cards. We specifically requested a 3D-model be created at an extra cost for the avatars. We created all printed components using Adobe Illustrator and Adobe Photoshop. We described the color for all items using CMYK and RGB coding.

The main channel for communicating with the manufacturer was email. Responses from the manufacturer were usually within 24-36 hours.

The production of the prototype took about three weeks. We received interim content pictures, which built our excitement and anticipation.

The shipment into the European Union (EU) required content specifications according to the details from the EU declaration of conformity to pass the customs control.

3.3 Lessons Learned

3.3.1 Gamification

The gamification canvas was an important tool in understanding the necessary components and considerations in designing the game. After two brainstorming sessions, the major behaviors and components for the initial development were identified. The components and dynamics were adjusted with each gameplay during the test phase.

3.3.2 Gameplay

During the gameplay sessions, it was apparent that personal enjoyment was a factor in how people reacted to the game. Each person wanted to reach the end of the game even if someone arrived their first. Otherwise, there was dissatisfaction with the game as a whole.

Initially, there was a basic assumption that everyone knew what a methodology was. Thus, the learning was different. However, this was not the case during the testing and validation stage. Thus, the learning could be broader than expected.

During the gameplay, other discussion points included observing:

- Different mental models are used to build team compositions, e.g., all one gender and geographic region.
- Lack of planning to reach the end of the play.
- Lack of contingency planning.

There was an imbalance in the start-up and playing times for the traditional/waterfall and agile players, reflecting real life. The traditional players require significantly more consideration during the initial planning but have fewer decisions during the gameplay. Conversely, the agile players require less start-up time but have more decisions during the gameplay. This imbalance had to be compensated for in the instructions to reduce the duration of the imbalance but maintain enough difference for the learning effect.

4. Discussion and Conclusions

We presented a novel game that engages a player in complex decision-making and allows them to experience the effects of their decisions; this allows non-managers to learn management responsibilities and translate that experience into knowledge. The game-based training was tested with industry practitioners and evaluated the participants' perceived learning.

The learning incorporated project management knowledge areas, specifically integration management, methodology selection, and value-driven management. The issues and opportunities allowed the participants to experience the uncertainty associated with typical project risks or opportunities they could not plan. When played competitively, the game drives the player to focus on value creation based on the associated methodology decision.

The absence of these project management skills is one of the biggest inhibitors to project success. Existing project management games lack the breadth of project management skills needed for complex project delivery. The existing agile methodology game fails to deliver management skills to team members. No identified serious game covers the decisions impacts of methodology selection on the project execution.

The inclusion of project management elements that coexisted with the agile methodology elements enabled the novice participants to learn about agile within the application context of new product development. The complexity of the product scope with the project management elements created situations similar to real-life challenges.

The observation of the participants and their reported learnings underscore the effectiveness of using a simulation game as a learning aid.

We plan to systematically evaluate the game impact using a quantitative evaluation tool to confirm these expected benefits and the long-term effectiveness of the learnings.

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Learning to Escape or Escaping to Have Fun? Do Educational Escape Rooms Positively Impact Students' Performance in Business Higher Education?

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Abstract: Interest in and the use of escape rooms (ERs) for educational purposes have increased recently (Taraldsen et al, 2020; Veldkamp et al, 2020). There are many benefits to using ERs in education, including improved engagement and motivation (Buchner et al, 2022; Taraldsen et al, 2020; Veldkamp et al, 2020). However, findings concerning the impact of the use of ERs on students' actual learning are mixed (Veldkamp et al, 2020). This study aims to investigate this impact by exploring a case in which a digital ER was implemented in a blended online course. This ER was designed to be used in a business course including more than 150 business undergraduate students distributed across 15 campuses. The specific learning objective of the escape room was to enhance students' understanding of the most important concepts of the course in preparation for the midterm examination. The authors compare students' performance across two different sections of the same course, i.e., a control section and another section in which the ER was implemented. In addition, the authors administered a survey to comprehend students' ER perception. Results show that while students had a positive perception of the use of the digital educational ER, its usage did not affect their performance on the midterm examination.

Keywords: active learning, escape room, higher education, business

1. Introduction

Since their introduction in 2007, the use of escape rooms (ERs) has increased exponentially, beginning in Asia and later expanding to Europe, Australia and North America (Nicholson, 2015). ERs have also been used in a widespread manner for more purposes than entertainment, gaining a foothold in the field of education (Taraldsen et al, 2020; Veldkamp et al, 2020). A vast number of educational escape rooms (EERs) have been documented in fields such as medicine and computer science (Veldkamp et al, 2020). However, evidence concerning the use of ERs in business education remains scarce. Furthermore, evidence concerning the use of digital educational escape rooms (DEERs'), i.e., EERs that are conducted remotely using digital tools (Gordillo et al, 2020; Huang, Kuo, and Chen, 2020; Makri, Vlachoupoulos, and Martina, 2021), is also limited. This article aims to illuminate these topics in further detail. Two research questions guided this study: Does the use of a DEER positively impact students' course performance? What are management students' perceptions of the use of a DEER?

We developed a DEER for a blended undergraduate course offered every semester with an average enrollment of more than 150 students distributed across 15 campuses that are in different cities. The design of the DEER was intended to enhance students' knowledge of the key concepts of the course and support their preparation for a midterm examination. The DEER was divided into three different phases or levels in which students were asked to solve a puzzle related to the topics of the course. At the end of the DEER, students discovered a room where they could participate in additional review of the contents discussed in the course. The midterm exam was administered two weeks after students completed the DEER. Following completion of the DEER, students answered a survey regarding their experience. In addition, the performance of these students on the midterm exam was compared to the performance of students in another section of the class of a previous semester. Data showed that while students' perceptions of the impact of the use of the DEER as preparation for their exam were positive, their grades were not significantly different from those of students in the section that did not use the DEER.

This work consists of five sections. The first section explores the theoretical background. The second section explores the methodology of this research and describes its different stages and overall process starting with the academic design of the DEER. The third section presents the findings of the study. The fourth section discusses the limitations of the study. Finally, the fifth section presents the conclusions of the study.

2. Theoretical background

The use of ERs in education is related to two other trends: gaming and experiential learning. Gaming has been established as a common strategy to facilitate learning at all academic levels and can be defined as "the use of game design elements in non-game contexts" (Deterding et al, 2011; pp. 9). This technique consists of transferring the concepts and mechanics used in games to an educational context. In recent years, the gaming strategy has evolved into a variety of more realistic activities. In turn, experiential learning or active learning is a new approach to the learning process. It engages students with specific learning content to enable them to acquire and secure new knowledge and increase their ability to retain information (Strickland & Kaylor, 2016).

Originally intended for recreational purposes, ERs can be defined as "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 time" (Nicholson, 2005; p .1). ERs were also developed to use physical space in designing players' experiences. The first documented escape room was created by a company called SCRAP and was known as the "Real Escape Game" (Nicholson, 2015). This ER was conducted in Kyoto, Japan, in mid-2007 and consisted of a game featuring one room in which teams including 5 or 6 people participated. Since that time, recreational ERs have expanded at a rapid rate from Asia to Europe and later to Australia and North America (Nicholson, 2015).

When educators became aware of the possible benefits of using ERs to challenge and test students' knowledge of specific topics or concepts, a natural evolution of their application to educational environments took place. When ERs are used in education, students are involved in the learning process in a fun format that can be beneficial with respect to their achievement of learning goals. In this case, the escape room is part of the objective of gamification. Educational games are explorative, problem-based learning scenarios that may be fun but do not truly contribute to learning without the inclusion of additional instructional elements (Buchner et al, 2022; Taraldsen et al, 2020; Veldkamp et al, 2020).

Interest in and the use of escape rooms (ERs) for educational purposes have increased recently (Taraldsen et al, 2020; Veldkamp et al, 2020). EERs are widely used for developing skills in a variety of fields, such as medicine, social sciences, and computer science; however, their use in the field of business education appears to be lacking. EERs are designed to take into account the preferences and characteristics of a concrete group and the desired educational outcomes (Veldkamp et al, 2020). This type of resource is immersive, which entails that they are focused on "providing information or stimulation for a number of senses, not only sight and sound" ("Immersive", 2022). The intention of EER designers is to facilitate higher levels of success because EERs represent a positive experience for students while simultaneously allowing them to attain the expected learning goals (Veldkamp et al, 2020).

Some of the benefits of using escape rooms in the context of education are the active participation of students, stimulation of their learning through play and the incorporation of puzzle solving as an educational challenge. Both students and teachers perceive that while participating in escape rooms, students are more engaged and active than in the case of regular classes (Cain, 2019). In addition, escape rooms encourage collaboration and teamwork, since team members must make decisions jointly to obtain answers. Students also learn to work under pressure since they have limited time to complete the exercise.

Learning via EERs is associated with increased learner engagement and motivation, which can in turn positively affect learning achievement (Buchner et al, 2022; Taraldsen et al, 2020; Veldkamp et al, 2020). In an escape room, students make the decisions, and the professor plays the role of a guide, occasionally even allowing students who make mistakes to learn from them and move forward. This situation allows students to become involved in the learning process, motivates them and is simultaneously fun for them.

Both professors and students have expressed a positive perception of the implementation of an EER; it is considered to serve as a good resource for developing a better understanding of the information and applying or practicing knowledge, and it also functions as an instrument for evaluating the concepts and skills that students develop (Veldkamp et al, 2021). In summary, using different tools to encourage and evaluate students provides a more extensive means of assessing their learning outcomes and changes the ways in which feedback is provided as well as the way in which relationships with students are developed.

A great deal of literature has investigated the successful implementation of EERs. Several recommendations have been made based on empirical knowledge, particularly by the authors Veldkamp et al (2020). Some of these recommendations include the following: every effort must be focused on achieving the desired learning outcomes by considering the most suitable pedagogical techniques and designs for the game; the role of the professors is challenging because they are required both to monitor and to guide the experience, but simultaneously, students must encounter a certain level of autonomy and immersion while performing the activity. Finalizing the game with a debriefing after is highly recommended. The duration of such a debriefing can vary depending on the ER and professors' choices, with some lasting for 5 minutes and others taking up to 2 hours. In such a debriefing, the professor encourages students to share their experiences, comments, or questions regarding the EERs and offers feedback concerning their results. In addition, professors using EERs must define the assessment carefully in accordance with the learning outcomes.

While the majority of EERs appear to be conducted in physical spaces, they can also take place remotely in virtual environments (Gordillo et al, 2020). In this case, the EER is designed by using digital tools (Gordillo et al, 2020; Huang, Kuo, and Chen, 2020; Makri, Vlachoupoulos, and Martina, 2021) that "can supplement the physical components in an EER" (Makri, Vlachoupoulos, and Martina, 2021, pp. 4). Digital educational escape rooms (DEERs) offer advantages such as reduced costs or increased convenience and adaptability (Makri, Vlachoupoulos, and Martina, 2021). In the following, we explain in detail how we designed and conducted this study.

3. Methodology

Two research questions guided this study: Does the use of a DEER positively impact students' course performance? What are management students' perceptions of the use of a DEER? This study employed an experimental approach to understand the effects of the use of a DEER on students' performance on a midterm examination. The study considered a control group that corresponded to a section of the course delivered in the fall semester of 2021. The treatment consisted of the implementation of a DEER in another section of the same course that was delivered in the spring semester of 2022. To comprehend students' perceptions of the use of a DEER we administered a survey. Data collected from both the experiment and the survey was analyzed. Next, we describe the design of the DEER and the process we followed to conduct this research.

The DEER had the specific learning objective of allowing students to review the most important concepts of the course and preparing students for the midterm exam. The DEER was implemented in the context of a business course including 160 business undergraduate students distributed across 15 campuses that were located in different cities. This course was a blended online course taught via team teaching. Accordingly, two professors were responsible for the live session and the general content of the course. Additionally, each student had a tutor professor who oversaw their assignments, shared important announcements, and provided personal follow-up to develop closer relationships with the students. This course featured one real-time session of one hour and a half conducted via Zoom once per week with the lead professors. Apart from the live session, students were required to work on their assignments for the week at their own pace and submit their deliverables to the Canvas Learning Management Platform (LMS) according to schedule. The course was 16 weeks long.

This study was developed via a five-stage process: academic design of the DEER, technical design, implementation, data collection and analysis (Figure 1).

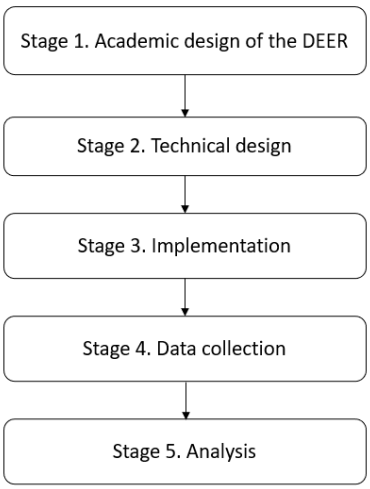


Figure 1: Stages of the development of the DEER.

3.1 Stage 1. Academic design of the DEER

During the first stage, the professors of the course determined the date on which the DEER was to be implemented. Bearing this date in mind, the content of the DEER was defined, that is, the topics to be covered were identified. After defining the topics of study, we identified the main concepts they included. Two main topics were selected, and for each topic, the authors planned the design of the DEER. The design focused on the development of puzzles related to the main concepts. The first puzzle consisted of a crossword featuring an acronym for the main concept. For the second puzzle three questions were included alongside appropriate clues, which consisted of a video, or an article intended to help students find the right answer. The initial academic design of the DEER took place over a period of two weeks, although the design was also refined during subsequent phases.

3.2 Stage 2. Technical design

The second stage was carried out in collaboration with the developers of the DEER. First, the developers required the authors to develop the storytelling associated with the DEER to ensure that the puzzles were aligned and introduced in a logical way. The second activity was the task of refining puzzles and how they were to be presented. A key consideration was and what the best choice would be to ensure that the students could have fun while solving the puzzle. The design choices lead to a sequential structure (Veldkamp et al, 2020) of the DEER. The developers prepared a templated featuring the rooms' sequence and the information required for each aspect of the room to guide the whole process, which was created using the application Figma (Figure 2).

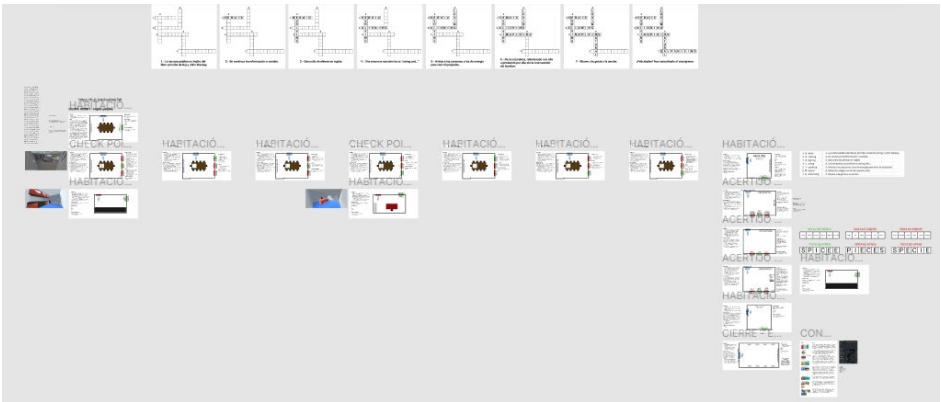


Figure 2: Figma of Digital Escape Room

The developers proposed the use of the Mozilla Hubs digital application based on the technical requirements of the DEER's design. Follow-up meetings were conducted every two to three weeks, and during these meetings, adjustments were made to the design of the DEER. The final design comprised 14 rooms around 2 main puzzle types. Among these rooms there were rooms that served as transitions and the final one which was dedicated to the review of topics of the course.

Once the final version of the DEER was complete, the authors tested it. Once the DEER was approved, the developers generated one link for each of the teams from the section of the course. The technical design step had a duration of approximately two months. Next, we describe the DEER in more detail.

The storytelling of the DEER focuses on the succession of a company and a main character named David, who is the new leader of the organization and wants to align the organization with the characteristics of a conscious company. This character invites the students to help in this process by completing the puzzles in the rooms to advance. David and the company are introduced in a room that does not include a puzzle (Figure 3). After completing this introductory room, students advance to Room 1 (Figure 4), in which they are required to solve the first puzzle (Figure 5).



Figure 3: Introductory Room.

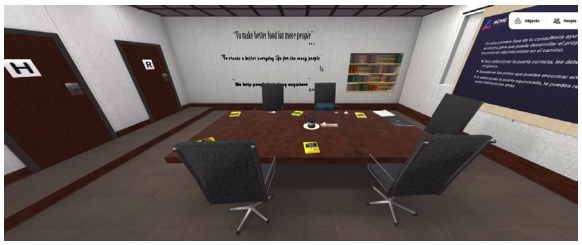


Figure 4: Room 1.

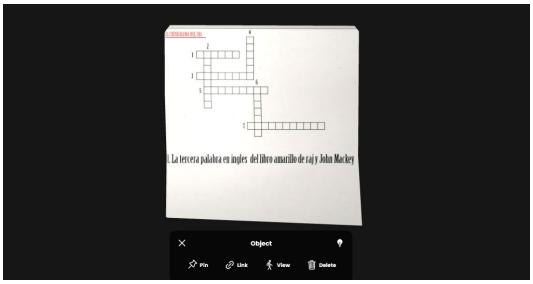


Figure 5: Riddle of Room 1.

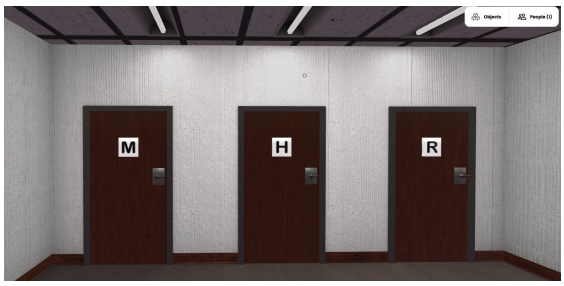


Figure 6: Escape Room Doors.



Figure 7: Sample of a Clue.

The first puzzle consists of a crossword. To advance to the next room students need to choose the door that corresponds to the first letter of the word that meets the criteria of the crossword (see Figure 6). In case they do not know which door to choose, clues (see Figure 7) are available in all rooms. If students choose the wrong door, they enter a kitchen or an office, while if they choose the correct door, they continue to the next element of the crossword (Figure 6). By finding the right answer and choosing the correct door students continue advancing though the rest of the crossword. In each new room students see the progress made with the crossword. They advance until the crossword is completed and reach a transition door that congratulates them and leads them into a room with the second puzzle which consists of a set of questions. Students must solve 3 questions that correspond to 3 different rooms to access the final room where the main character of the story awaits to congratulate and thank them for their help. In this final room there is review of concepts related to the topics included in the DEER (Figure 9). By approaching the screen elements of the room, students see and hear a video that explains the main topics of the course.



Figure 8: Second Puzzle.



Figure 9: Final Room of Digital EER.

3.3 Stage 3. Implementation

To enable the students to familiarize themselves with the digital application used to complete the DEER, the authors assigned a practice activity one week before administering the DEERs. This activity was a non-formative practice activity featuring a single room using the same digital application that was used for the DEER. Students were required to submit evidence of completion merely to collect evidence concerning who completed the assignment. The DEERs were conducted one week prior to the scheduled time for the midterm examination. All instructions for the activity were available in an activity on Canvas LMS.

On the day when the DEER was conducted, the Zoom session started with general comments regarding the previous week, and then the authors provided the general instructions for the DEERs. The students were divided into 33 breakout rooms for the course, and each team used a specific link to access the DEER. The DEER was scheduled to last 50 minutes, and teams could ask for help if needed. In the main session, the faculty and a technical support team were available in case any technical issue arose. Once students had completed or the allotted time had passed, all teams returned to the main session. The session concluded with general announcements related to the course; following the session, students completed the feedback survey regarding their experience using the DEER.

3.4 Stage 4. Data collection

During the fourth stage, i.e., data collection, a survey was administered to students following their completion of the midterm examination. These questions were drawn from a prior work by Lopez-Pernas, which was published in December 2019. We discarded 4 questions that were specific to the context of the author (Lopez-Pernas, 2019). In addition, we adapted 2 questions, one that referred to the number of members of the team, and another that referred to the duration of the ER. The results of the survey are shown in the findings' section.

In addition to the survey, Data concerning the midterm exam grades of students in two different sections across different terms were collected. The terms selected were August to December 2021 and February to June 2022. We eliminated grades of zero for students who had dropped the course. For both terms, the number of grades was 160. For the term lasting from February to June 2022, we introduced open ended questions to the midterm exam; thus, to facilitate comparison to the term from 2021, we deducted the total of these questions (24 points) from individuals' grades and subsequently recalculated the grade based on the total number of points possible (76 points).

3.5 Stage 5. Analysis

The two research questions that guided the study demanded a different analytical approach. To understand the impact of the DEER on students' performance in the midterm examination, grades from both samples had to be compared using the statistical technique most appropriate to the data. To evaluate students' perceptions of the use of the DEER, simple descriptive statistics were calculated. Findings for both research questions are presented next.

4. Findings

The findings of this study can be divided into two sections. First, we present the results obtained after comparing students' performance on the midterm examination. Second, we discuss the findings related to the survey of students' perceptions of using the DEER.

To analyze the data from the Midterm grades, we begun by evaluating the distribution of the data. First, we generated density plots for the two samples, Fall 21 and Spring 22 (see Figures 10 and 11). The plots evidenced that both datasets were not normally distributed.

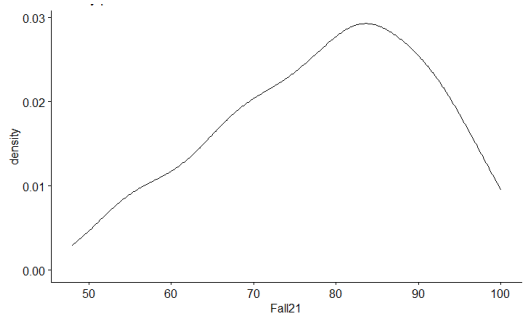


Figure 10: Density Plot Fall 21.

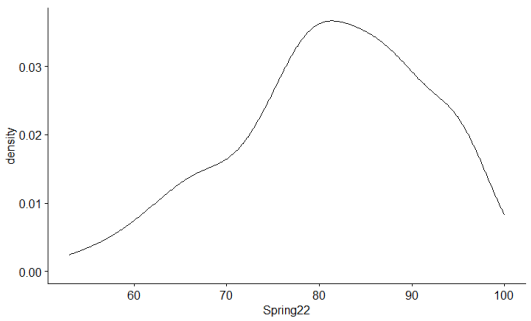


Figure 11: Density Plot Spring 22.

In addition, we tested both samples using the Shapiro–Wilk test, and the results (Table 1) confirmed that the data were not normally distributed.

Table 1: Results on the midterm examinations.

Shapiro-Wilk Test normality test	
W = 0.95311	p-value = 3.363e-05

The following hypotheses guided the rest of the analysis to evaluate the effect of the DEER use in student's performance.
H0: $\mu 1 = \mu 2$ The use of escape rooms improves students' performance on midterm examinations.
H1: $\mu 1 \neq \mu 2$ The use of escape rooms does not improve students' performance on midterm examinations.

Because the data did not fit a normal distribution, these hypotheses were tested using the Wilcoxon formula in RStudio. Wilcoxon test results are shown in Table 2.

Table 2: Results on the midterm examinations.

Period	Number of students	Mean	Std Deviation	Variance	Wilcoxon	alfa$\alpha = 0.05$
Fall 2021	160	79	12.62	159.28	W = 11680 p value = 0.1748	
Spring 22	160	81	10.33	106.81		

After conducting the Wilcoxon test, H0 could not be rejected. Thus, the results show that students' performance does not differ significantly when a DEER is implemented. In the following section, we discuss the limitations of this study.

Concerning the survey administered to students following the completion of their midterm examination, most respondents noted that their experience with the DEER was positive, with almost half of respondents declaring that it was very good (Table 3). The trend was the same regarding students' perceptions of the impact of the DEER on their mastery of knowledge pertaining to the course. Their perceptions of fun were even more positive, with almost 56 percent of students rating their degree of fun as 5. Moreover, students agree that the experience was immersive. This finding is interesting, as the DEER was designed to use a virtual platform instead of a physical space. In contrast, students' responses regarding the levels of stress provoked by the DEER exhibited more variation. Students mostly felt stressed while participating in the DEER.

In terms of the difficulty of the DEER, according to the survey results, more than 80 percent of students perceived that while completing the activity was relatively easy, the difficulty of such completion was related to the student's mastery of the course contents. Students' responses showed that overall, they felt prepared to succeed in the DEER.

Table 3: General results of the survey.

Question	Average	Std Dev
1. What is your general opinion on the escape room? (1 poor - 5 very good)	4.13	1.04
2. The escape room allowed me to improve my knowledge of the course materials (1 strongly disagree - 5 strongly agree)	4.13	1.03
3. The escape room was fun for me (1 strongly disagree - 5 strongly agree)	4.16	1.14
4. The escape room was an immersive experience (1 strongly disagree - 5 strongly agree)	4.13	1.14
5. The escape room was a stressful experience (1 strongly disagree - 5 strongly agree)	2.93	1.47
6. The escape room was too difficult (1 strongly disagree - 5 strongly agree)	2.66	1.45
7. The difficulty of the escape room lies in the mastering the course materials (1 strongly disagree - 5 strongly agree)	3.64	1.22
8. I think I was sufficiently prepared to succeed in the escape room (1 strongly disagree - 5 strongly agree)	4.18	0.86
9. The escape room was well-organized (1 strongly disagree - 5 strongly agree)	4.12	1.10
10. The duration of the escape room (50 minutes) was adequate (1 strongly disagree - 5 strongly agree)	4.02	1.06
11. I wish I had received more help during the escape room (1 strongly disagree - 5 strongly agree)	3.13	1.40
12. The initial guidance provided was enough (1 strongly disagree - 5 strongly agree)	3.88	1.09
13. The supervision of the activity was adequate (1 strongly disagree - 5 strongly agree)	4.13	1.05
14. I liked participating in the escape room with a team (1 strongly disagree - 5 strongly agree)	4.25	1.15
15. I would rather have participated in the escape room on my own (1 strongly disagree - 5 strongly agree)	2.67	1.55
16. All members of the team were equally involved in solving the different puzzles (1 strongly disagree - 5 strongly agree)	4.04	1.21
17. Would you like other courses to include activities like this (even if it was not for a grade)?	Yes 83%	No 17%
18. Would you recommend other students to participate in the escape room (even if it was not for a grade)?	Yes 83%	No 17%

Overall, students' answers to questions regarding the design of the DEER were positive. Most students noted that they thought the DEER was well organized and that its duration was appropriate. Opinions pertaining to the assistance that students received during the experience exhibited more variation. More than 80 percent of students reported that the guidance and supervision associated with the DEER was adequate. Students were positive regarding the notion of solving the DEER as part of teams rather than participating by themselves. The engagement of team members appeared high with more than 70 percent of students felt all team members were involved in solving the puzzles.

The results of the survey showed that most students want more courses to include DEERs, and they recommended that other students participate in EERs even if the activity is not graded.

5. Limitations of the study

This study faces certain limitations. First, the format of the midterm examination was changed between one term and the other. Specifically, open-ended questions were included. While we omitted the scores pertaining to questions that were different from those used during the August 2021 term, it is possible that this adjustment could have had an impact on the scores used for the February term. Second, the DEER was designed and executed in the form of a team activity; thus, students' performance on the midterm examination was not necessarily influenced by students' completion of the DEER equally across all students. A third limitation is related to the technological requirements of the DEER. Some students experienced technological difficulties and participated by following their peers' navigation screens via Zoom. In addition, because not all operating systems supported the application, some students could not have the same experiences as others. Moreover, students did not receive the same levels of support during their DEER experiences. Some teams received more attention and guidance during the activity than others. A fifth limitation is associated with students' familiarity with the application itself. While the design of the DEER activity also included a preparation activity, this activity was assigned as homework, and as a result, it was not completed by all students.

6. Conclusions

This article aimed to investigate the usage of DEERs in business education, in particular in the context of ERs developed in a digital environment. Two research questions guided the study. First, how do students perceive the use of DEERs in a management course? Second, does the use of DEERs have a positive impact on the performance of students? The results showed that while students' perceptions of the use of DEERs were mostly positive and they believed that the activity had improved their mastery of the subject, there were no statistically significant differences in their performance.

ERs were originally used for recreational purposes (Nicholson, 2015). However, they have become popular in educational settings as a tool to fulfill learning objectives (Buchner et al, 2022; Taraldsen et al, 2020; Veldkamp et al, 2020). This research showed that while the improvement of educational objectives through the use of ERs is uncertain, the recreational objective of such an approach appears to be achievable. Such findings invite us to encourage further research concerning the usefulness of ERs as an educational resource to support the fulfillment of learning objectives.

Conclusions and specific recommendations can also be drawn at the level of the design and implementation of DEERs. First, instructors should carefully design a DEER to ensure its coherence with the learning objectives. Because DEER development may require specialist support, the coordination and use of graphical interfaces to understand the architecture of these rooms is encouraged. In terms of the application of DEER, instructors should consider students' levels of preparation. Accordingly, we recommend administering a tutorial or a trial test before implementing a virtual escape room during class so that the students can familiarize themselves with the immersive activity instead of being worried about potential technical issues. Ensuring that technical support and guidance is available to students during the activity is also important. In addition, the accessibility of the digital platforms for DEERs must be ensured.

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Is a Board Game Suitable for Teaching Complex Natural Systems? Yes

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Abstract: The quality of people's daily lives is dependent on the functioning of natural systems - ecosystem services. These services are essential for social and economic development of our society and for ensuring the well-being of humans. This dependency is not easily understandable, as it is non-linear. The use of games has been proven a successful method in teaching complex systems. Games can improve, besides knowledge, students' social and academic achievement, promote students' motivation, improve their critical thinking and co-operation skills. In this research we assessed how an ecosystem services themed board game „End of the World Begins in Kurtna" supports students' ability to understand the relationship between humans and nature. We evaluated the game's potential as an educational tool to foster better comprehension of the concept of ecosystem services. To validate the game's usability and learning value, game sessions were conducted with more than a hundred students. To collect their knowledge about both ecosystem services and nature, their attitudes towards the game and their subjective assessment of their own knowledge, pre-test and post-test questionnaires were used and the data was analysed using mixed methods. The results present that the game enhances the understanding of relations between humans and nature and helps to notice causality related to the subject. The game makes players perceive the human impact on nature and creates a positive attitude towards protecting the natural environment. The majority of respondents found the game to be interesting and engaging. Since interest and engagement are closely related to motivation we conclude that the game also has a positive effect on learning motivation. We conclude that board games can be suitable means for understanding complex terms such as ecosystem services. The game is applicable for enriching natural science education and is a good supporting material for teaching. However, since we did not measure knowledge retention over a long period of time we cannot confirm the game's ability to enable deeper understanding of the subject.

Keywords: ecosystem services, board game, natural sciences, GBL, educational games

1. Introduction

Ecosystems provide us with services necessary for people's well-being and for the social and economic development of society (Costanza et al, 1997; MEA 2005). The environment and nature, including ecosystem services, have complex ways of operating and are therefore not linear (MEA, 2005). However, it is difficult to convey knowledge about nonlinear and complex systems to students in a linear way (through words and sentences). One possible way to enhance the understanding of complex systems is through educational games (Castronova & Knowles, 2015). Games have become increasingly popular, with more and more games being used for educational or training purposes (Jesmin & Ley, 2020). The role of educational games in the learning process has been studied in the past and is a common strategy in the classroom to increase student engagement (Ke et al, 2015). For example, in Estonia game-based learning (GBL) is widely used in classrooms (Jesmin & Ley, 2020). This paper provides an overview of an Estonian ecosystem services themed board game „End of the World Begins in Kurtna" which is designed for educational purposes. The goal of this research is to assess the potential of the game to provide students with knowledge about nature and promote understanding of the concept of ecosystem services. Therefore, the game „End of the World Begins in Kurtna" has great potential to be an important educational tool in natural sciences education.

Education in ecosystem services could be an effective means of conveying knowledge about the importance of different ecosystems and people's dependence on these complex systems. Ecosystem services framework can be used to learn about the structure, functions and different assessment methods of ecosystems as well as the impact of human activities on these self-regulating natural systems (Torkar, 2016).

2. Context

2.1 Ecosystem Services

Ecosystem services (ES) are widely acknowledged as goods ecosystems provide to humans. These goods can be provisional (food, freshwater, fuel, medicine), cultural (recreation, aesthetic value) or have a regulating or a supporting purpose (pollination, climate regulation, soil formation, biogeochemical cycle). Millennium

Ecosystem Assessment (MEA) defines ecosystem services as the benefits humans receive from nature due to certain conditions and processes (MEA, 2005). The second most common approach is the TEEB (The Economics of Ecosystems and Biodiversity) definition describing ecosystem services as „the direct or indirect contribution of ecosystems to human well-being" and looks at benefits and services separately. However, the concept of ES is relatively new. The concept was first mentioned by scientific literature in 1981 and only gained public attention in the late 1990s (TEEB, 2010). Understanding how ecosystem services relate to biodiversity, social and economic aspects aid in developing more sustainable and nature-based solutions (Burkhard & Maes, 2017). The complex environmental issues we are facing today require an educated public (UNESCO, 2017).

2.2 Game-Based Learning

Involving students in classroom activities has become increasingly difficult over the years. As a result, there is a need to implement other teaching strategies that improve student engagement, such as game-based learning. GBL is often associated with computer games but can be applied to non-digital games as well. Game-based learning often conveys „serious" subjects through games and allows the player to gain new knowledge and skills (Laamarti et al, 2014).

Previous research (Hsiao et al, 2014; Anastasiadis et al, 2018, Zainuddin et al, 2020; Yu et al, 2021) has found that engagement, interest and motivation are closely related and they play an essential role in improving players' learning ability, acquisition of knowledge and help enhance factual knowledge and cognitive skills. Educational games provide players with a safe space to learn through trial and error (Zeng et al, 2020) as they are merely models of real life. Game-based learning can have other advantages like providing immediate feedback to player's actions (Toda et al, 2019) and creating a more positive attitude towards their knowledge, skills and learning in general (Sitzmann et al, 2010).

There are not many ecosystem services related games, however, there are plenty of ecology-themed tabletop games (e.g. Parks (2019), Photosynthesis (2017), Endangered (2020), Canopy (2021)) and several ecosystems and climate-related board games. Some have been researched and proven to have a positive impact on players' knowledge. Eisenack (2012) found that a climate change themed board game „Keep Cool" prompts discussions and facilitates better understanding of a complex subject and its terminology. Phoomirat et al (2018) concluded a board game about green roofs helped players understand the benefits and ecosystem services these roofs could provide and inspired some of them to do additional research on the subject. Gitgeatpong & Ketpichainarong (2022) researched the ability of an educational board game „Mangrove Survivor" to help teach interspecies relations in mangrove systems and the environmental impacts affecting the habitat, concluding that the game created a positive perception and can be an effective learning tool and assist in understanding.

2.3 The Board Game

„End of the World Begins in Kurtna" („Maailmalõpp algab Kurtnas" in Estonian) focuses on ecosystem services and is an educational role playing board game which shows the impact of economic activities on our natural environment. The game takes place in Kurtna Lake District, which is a part of the Alutaguse National Park located in the North-Eastern Estonia. The Kurtna Lake District is unique for its diverse landscapes, abundant lakes of thermokarst origin, diverse ecosystems and habitats for protected species. It is also a transitional zone between densely populated and heavily industrialised oil shale mining region and a sparsely inhabited territory with large forests and mires. North-Eastern Estonia is heavily affected by human activities. The lakes of Kurtna have been deteriorated by peat milling, mining of oil shale, sand mining from the Pannjärve quarry and by excessive groundwater intake to provide drinking water to the nearby towns. Due to these anthropogenic activities lake levels have dropped, water chemistries and lake ecosystems have changed. (Terasmaa et al, 2014; Vaasma et al, 2015; Vainu et al, 2020)

All this makes the Kurtna region an ideal example of showcasing conflicts between economic needs and ecosystem services. The game „End of the World Begins in Kurtna" uses those real-life problems in Kurtna Lake District as an example to illustrate both the positive and negative impact humans have on ecological balance. Each decision and action taken by the player affects the course of the game and determines if the in-game world is moving towards sustainable management or the end of the world.

The game has been created with the help of Tallinn University students as a part of two interdisciplinary collaborative projects (LIFE). The LIFE project is a part of all study courses and it focuses on project- and problem-based learning. The designing process brought together students from different fields of study (e.g. educational

technology, environmental management and pedagogics) providing a diverse background for developing the game. The goal was to create a fun and educational board game for introducing ecosystem services. The designing process took two years and the game's latest version was released in 2019. The game has a total of 22 authors, including the project supervisors Jaanus Terasmaa and Triinu Jesmin.

2.3.1 Learning Value

At the heart of the game is a player whose task is to achieve the goals set in their role. Players' actions in the game have direct and indirect, immediate and delayed effects on the environment. Some actions do not appear to affect the environment at first. However, the impact can manifest gradually and the consequences of one's actions (both positive and negative) may cause a domino effect, similar to real-life settings. The domino effect can change the course of the game, make achieving goals more difficult or even end the game. This helps to bring to players' attention when managing ecosystem services and natural environment in general, both in the game and in real-life situations, sustainability takes precedence over short-term solutions. According to the creators of the game, depiction of causality in the game helps to illustrate cause and effect between nature and man and in nature in general, and improve analytical abilities. Castronova & Knowles (2015) also propose that educational games help to understand causal relationships and improve the development of new skills and knowledge.

Players' success is dependent on the actions and decisions made by other players. The cards in the game are designed to provide a fun and engaging way for players to interact and commence in non-verbal communication with each other and with the ecosystems on the gameboard. As suggested by Pornel (2011) social interactions play a part in making educational board games engaging for students. To avoid the „end of the world" players need to communicate, collaborate and make compromises. In addition to emphasising the importance of cooperation, this could also help enhance players' communication skills. Teachers also use games for improving students' social skills and willingness to cooperate (Jesmin & Rinde, 2018).

Another learning value of the game is to bring the concept of ecosystem and sustainability to players' attention. Understanding the balance between healthy functioning of ecosystems and their ability to provide us with necessary resources, societal, and economical needs could help players to grasp the concept of sustainability better (Burkhard & Maes, 2017). The game also teaches players more about the biota and environmental problems present in the Kurtna Lake District. Seeing the environmental problems, consequences of human activities and exploring possible solutions, the game could encourage players to be more environmentally aware, considerate towards nature and realise the importance of sustainability.

2.3.2 Game Mechanics

The game board (Figure 1A) includes lakes, fields, shrublands and local ecosystems such as grasslands, forests and swamps. The board is divided into 30 hexagonal fields, each with its own ecosystem. Each hexagon has different features and requirements for interacting with them in the game (Figure 1B). The game includes 6 different types of cards: Role Cards, Ecosystem Service Cards, Action Cards, Development Cards, (+) Cards and (-) Cards. Other elements of the game are the Doomsday Clock, scoring tokens and game pieces. The recommended number of players is 4-6.

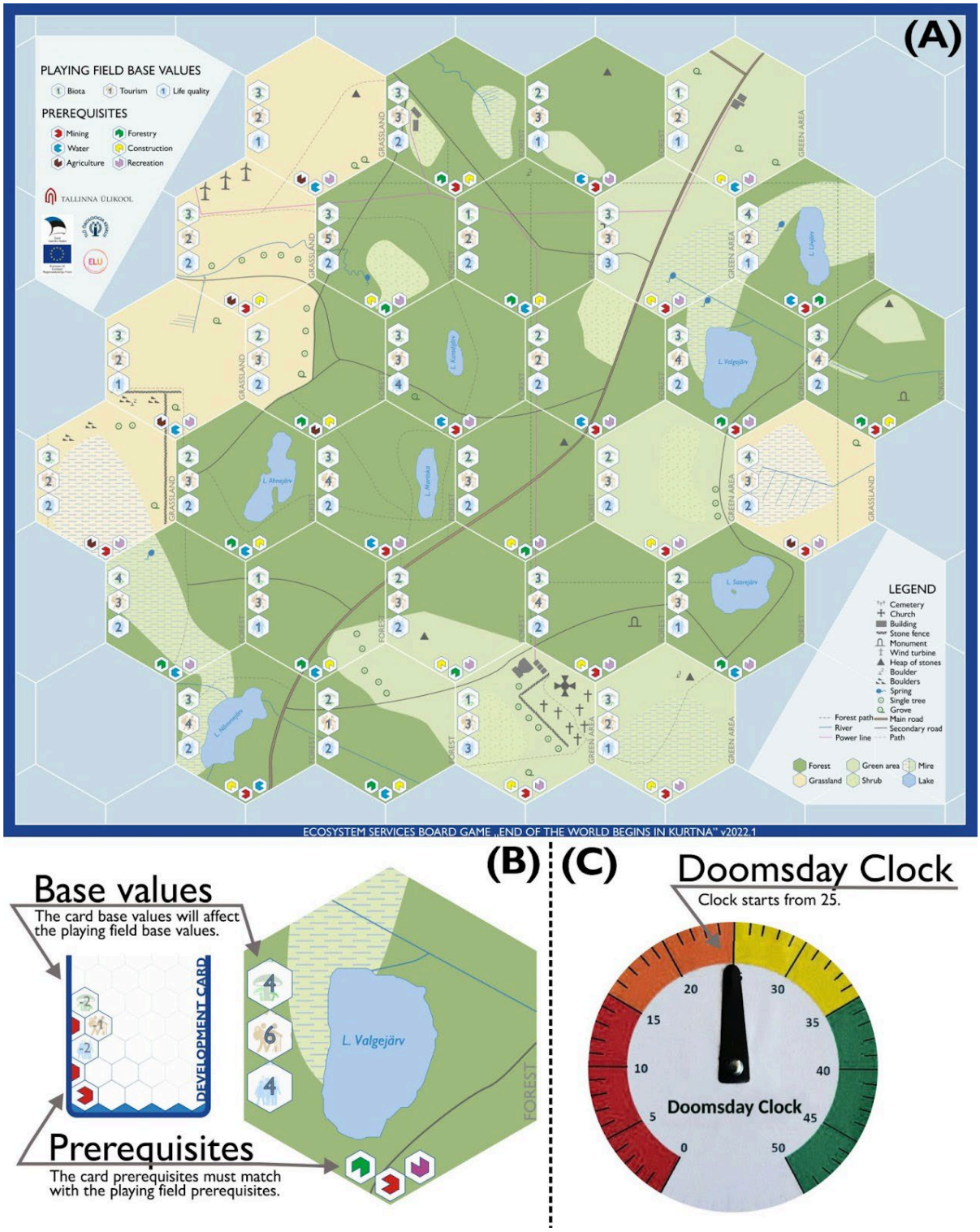


Figure 1. The board of the game „End of the World Begins in Kurtna" (1A), playing field (1B) and Doomsday Clock (1C)

At the beginning of the game, each player draws a Role Card. The goal of the player is to complete the task indicated on the Role Card without making the „world end" (except for the role of the „Apocalypticist", whose sole task is to make the world end). The first person who achieves their goal, wins. Additionally, each player will draw 2 Activity Cards, 2 Development Cards and 2 Ecosystem Service Cards. The number of cards can be changed to make the game more challenging or to provide variety. Development Cards enable players to engage in economic activities, Ecosystem Service Cards can be used to provide nature with ecosystem services and improve its condition, and Action Cards describe other human-related activities that impact the game's world

and other players (Figure 2). (+) and (-) Cards illustrate consequences of different actions and can create a positive or a negative domino effect.

- Development Cards: Players can create different facilities (e.g. wind parks, camping sites, different mines, adventure parks, groundwater extraction sites) and engage in other economic activities (e.g. grazing, cutting forests, growing crops) to enhance local economic activity. Building activities and increased tourism has a negative impact on nature and decreases the score on the Doomsday Clock.
- Ecosystem Service Cards (ES Cards): These cards provide the game's nature with ecosystem services. Service cards have a positive effect on nature and help to improve both living conditions and stabilise the environment so that it is more resistant to human impact and allows continuation of economic activities.
- Action Cards: These represent a wide range of other different socio-economic activities and events (e.g. accidents in mines, renovations, planting trees, wildcrafting, fires, economic crisis, cleaning). However, most of these actions have a negative effect on nature.

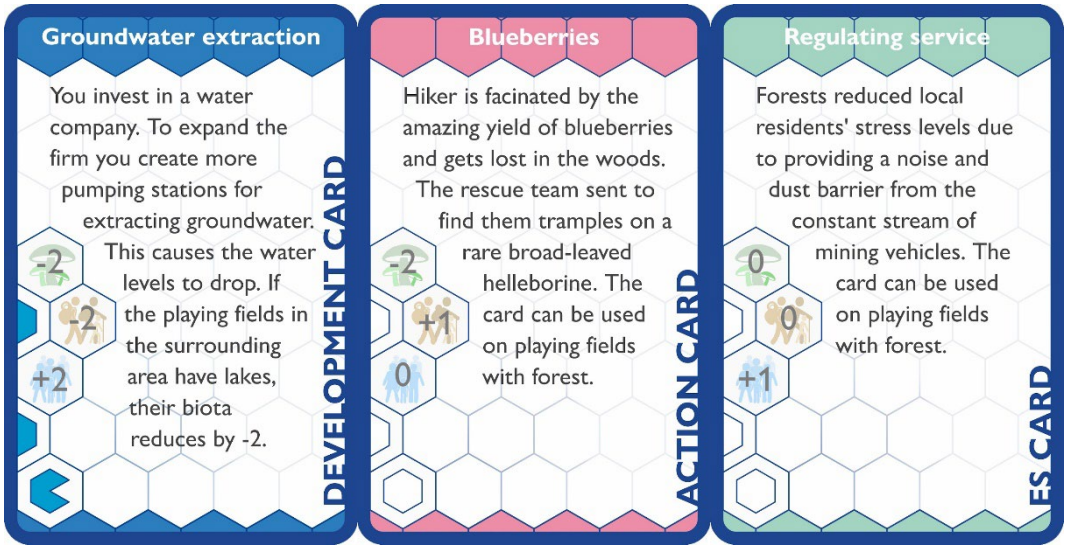


Figure 2. Examples of game cards: a Development Card, an Action Card and an ES Card.

All cards affect the base values of the playing fields and consequently, the score on the Doomsday Clock. The clock (Figure 1C) is an indicator of the well-being and resilience of ecosystems, thus keeping track of the state the nature is currently in as well as informing players of their impact on the game's ecosystems. After using a card the new values of the affected hexagon(s) will be calculated immediately. The change in values either increases (the clock moves towards the green zone) or decreases (the clock moves towards the red zone) the clock's score. If the Doomsday Clock reaches zero, the world has ended and the game is over.

3. Methodology

The sample (N=84) consisted of young people of different ages (i.e. voluntary work groups) between ages 12-26. They took part in game sessions and filled out a questionnaire consisting of a pre-test and a post-test. Each group of players attended an educational game session of about 2 hours. The game session consisted of an introduction to the purpose of the activity, a substantive introduction (very short review of ecosystems and ecosystem services), a breakdown of the rules, active playtime and answering the pre- and post-test. Active playtime was between 1-1.5 hours on average and the introduction part took around 15 minutes. A total of 6 game sessions were conducted and 16 different groups played on up to 4 boards simultaneously (4-6 players per board).

A web-based questionnaire consisting of a pre- and a post-test was used to collect the data. The pre-test was conducted before the introduction of the subject and the game, post-test was taken by the players immediately after the end of the game. The pre-test consisted of 7 questions and the post-test included 9 questions, both open-ended and closed-ended questions were used. The questions concerned participants' knowledge of ecosystem services and nature in general (e.g. „What do you think ecosystem services are?"), their attitudes towards the game (e.g. „This game sparked my interest"; „This game was engaging"), subjective assessment of

their own knowledge (e.g. „The game made me understand the relationship between nature and man better"; „I could explain to my peers what ecosystem services are").

To analyse the data collected from the game sessions, combined use of qualitative and quantitative methods were used. Descriptive and inferential statistics were used for closed-ended questions and qualitative content analysis for open-ended questions.

4. Results

We categorised the results into three different groups according to the theme of the questions. We also assessed how the content of the game overlaps with learning goals set out in the Estonian national curricula and determined the game supports the general competencies, learning objectives, organisational guidelines and cross-curricular topics.

4.1 Relations Between Humans and Nature

Post-game, the players considered human influence on the natural balance to be greater than before playing the game (Figure 3). The opinion of 23 people moved by one step and the opinion of 2 people moved by two steps towards a higher value. In self-assessment, all of these 25 respondents reported it became clearer to them what ecosystem services were. Additionally, more than half of the players agreed the game made them understand the relationship between man and nature better (i.e. 65% of respondents agreed or mostly agreed; 30% were hesitant). The players who answered „agree" or „mostly agree" also found humans' impact on nature to be greater than the players who answered „mostly disagree" or „disagree".

The open-ended question „Why do you think biodiversity is important?" that was present in both questionnaires, received noticeably more human-related answers in the post-test (37%) than in the pre-test (21%). For example, in the pre-test 15% of players mentioned how biodiversity is important for nature itself due to abiotic factors and organisms depending on each other. In the post-test this category did not receive any responses and instead players mentioned how man and nature affect each other. However, the post-test responses were shorter, less specific and less analytical. The rest of the answers were focused solely on the benefit of natural systems.

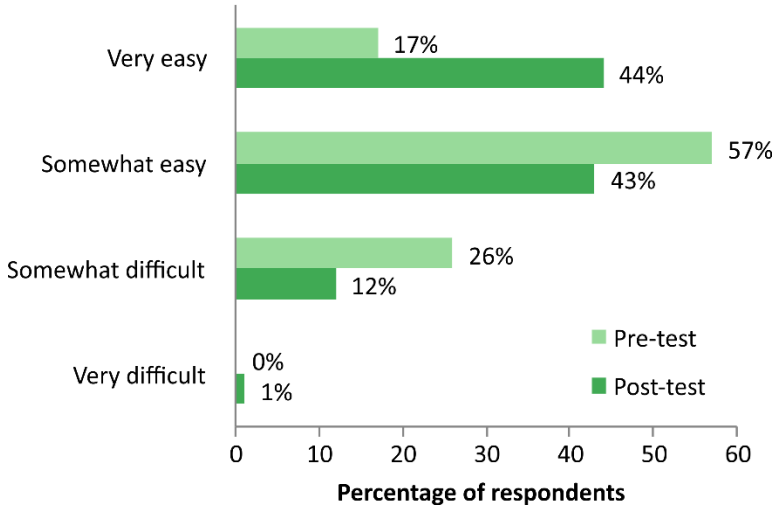


Figure 3. Pre- and post-test results of the question „How easy or difficult is it for humans to affect the natural balance?"

4.2 Knowledge About Ecosystem Services

There were mixed results in the understanding of ecosystem services. According to self-assessment, 94% of players found that after the game it became clearer to them what ES are. When asked „How would you describe what ecosystem services are?" the number of the most accurate definition for ecosystem services (i.e. „„Goods or services" nature provides for humans"), grew as well as human-nature related answers (Table 1). This was also the most popular answer. The category „„Services" related to „ecosystems"" are also mentioned multiple times.

Cultural services presented the least difficulties when identifying ES categories. Provisional services were also well-recognized and students were able to relate them with open-ended questions (i.e. „How would you describe what ecosystem services are?“, „Why do you think biodiversity is important?”).

However, when asked about players' ability to explain ecosystem services to their peers, only 19% of the respondents were confident („agree”), 48% either were hesitant or disagreed. Although many of the 48% had provided correct answers to the question „How would you describe what ecosystem services are?”. Answers to this open-ended question were mostly rather short, and had less variety and depth than in the pre-test. Additionally, more players gave unrelated answers or implied that they did not know (Table 1). Players also struggled with systematising and categorising ES with the most difficulties occurring in supporting and regulating services.

Table 1: Results of the pre-test question „How would you describe what ecosystem services are?” with example keywords

Category	Examples of keywords	Pre-test	Post-test
"Goods or services" nature provides for humans	Things, goods, services, humans, us	12 (14%)	16 (19%)
Knowledge	Educating, understanding, getting to know	4 (5%)	0
Sustainability	Ecofriendly, recycle, production	9 (11%)	2 (2%)
Human-nature interactions	Impact, providing, benefit, human, nature	0	10 (12%)
Food	Healthy eating	2 (2%)	0
Preserving nature/life	Protect, support, sustain, nature	8 (10%)	3 (4%)
Nature conservation	Nature reserve, conservation, ecosystem, nature	6 (7%)	0
Unspecific things that help nature	Developing, helping, balance	5 (6%)	0
"Services" related to "ecosystems"	Services, providing, ecosystem, relating	11 (13%)	8 (10%)
Naming specific ecosystem services	Improve air quality, foraging, oxygen	9 (11%)	4 (5%)
Do not know	"I have no clue", "?"	9 (11%)	6 (7%)
Other	Area, surroundings, living being	3 (4%)	4 (5%)
Unrelated answers	"Rather not answer", "Same as before"	2 (2%)	7 (8%)

4.3 Interest and Engagement

80% of players found the game to be interesting, 78% of players found the game to be engaging and the results presented correlation ($r=0,744$; $p<0,001$). This means that players who found the game to be interesting, also considered the game to be engaging. Additionally, the respondents who found the game to be interesting also answered „agree” or „mostly agree” when asked about their ability to explain the concept of ecosystem services to their peers.

5. Discussion

Players found that the game was engaging and sparked interest in them, which creates a positive attitude towards learning. The players' positive attitude towards their own abilities and the game as well as engagement and interest are important factors in enhancing academic results (Sitzmann et al, 2010; Hsiao et al, 2014; Anastasiadis et al, 2018; Yu et al, 2021). As motivation is often a key component in improving learning and its outcomes we conclude these are promising results and provide us with confidence in the game's suitability in being an effective educational tool.

The results showed that the game helps to illustrate causality between human activities and the natural environment. This is most likely the result of each card having some kind of effect on the game world, due to the Doomsday Clock element and it causing players to draw (+) and (-) Cards as the game progresses. Other researchers point out that games can provide immediate feedback to players (Toda et al, 2019), and games can be suitable for teaching associations and causality (Castronova & Knowles, 2015). In teaching human-related subjects like ecosystem services, causality can be a valuable concept due to ES (including natural balance and biodiversity) being affected by human activities. According to Burkhard & Maes (2017), understanding consequences of humans' actions plays an essential part in understanding ecosystem services and the overall complexity of natural systems. Previous research on game-based learning has similarly found that nature-related board games can help to teach complex nature- and ecosystem services-related systems (Eisenack, 2012; Phoomirat et al, 2018; Gitgeatpong & Ketpichainarong, 2022).

According to players' self-assessment, the majority found the game helped them understand the concept of ecosystem services better and in the post-test more players were able to provide a more accurate description of ES. However, the results were mixed. The post-test replies were shorter, had less depth to them and many players did not know how to answer. The respondents struggled with describing the concept and categorising the services (especially supporting and regulating services). This can prove to be an important knowledge gap and greater emphasis might be needed on these categories when teaching ES. It seems players did not understand ES as well as they had initially thought. Castronova & Knowles (2015) point out that it can be difficult to change people's perceptions about the functioning and interactions of complex systems. We believe that playing the game only once is not sufficient for making the concept of ecosystem services clear. As we consider the students impatientness while filling in the post-test to move on to other activities, we propose the shallowness of the latter answers could be pinned to that fact.

Despite the mixed results the game makes players feel smarter (related to motivation, interest, and engagement (Anastasiadis et al, 2018)), helps to explain the concept and assists in understanding humans' role in it. Further research should be done to study the effects of repeated gameplay on attaining new knowledge. The board game achieved the learning values highlighted by the authors such as engagement, interest, motivation and therefore improved understanding of the complexity of ES. Another reason to believe the game is a suitable educational tool is its correspondence with the learning goals set out in the Estonian national curricula. Due to the latter and the widespread adoption of GBL in the classroom (Jesmin & Ley, 2020) the game may gain popularity, especially in Estonia.

6. Conclusions

The objective of this paper was to assess the potential of an Estonian ecosystem services board game called "End of the World Begins in Kurtna" to provide players with knowledge about nature and promote understanding of the concept of ecosystem services. The game creates a positive attitude in the players about learning and ecosystem services, demonstrates causality, and makes players notice and perceive human impact on nature. As the understanding of human-nature relationship is closely related to better understanding of the ecosystem services, it supports teaching the concept. The game achieved the learning values highlighted by the authors such as engagement, interest, motivation and therefore improved understanding of the complexity of ecosystem services. Since in game-based learning interest and engagement are closely related to motivation and improved academic results, it concludes the game has also a positive effect on learning motivation.

However, post-game the players rated their ability of explaining ecosystem services to their peers moderately and we could not prove deeper synthesis of knowledge in explaining the concept of ES after the game. Players also faced difficulties in systematising ecosystem services which is still an important knowledge cap. The impact of a game session on gaining new knowledge about ecosystem services was not as good as the players

themselves had initially thought. We suggest that a single game session does not make the ecosystem services concept clear. Although it makes players feel smarter the results are insufficient to confirm the game's ability to provide a deeper understanding of ES and knowledge retention. Further research should be done to study the effects of repeated gameplay on attaining new knowledge. However, playing the game helps to clarify the concept and enhance understanding of human impact. We have proven that the game is suitable as an educational tool, can be used for enriching natural science education and is valid as a good supporting material for teaching.

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Playful Participatory Mapping: Co-creating Games to Foster Systems Thinking

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Abstract: This paper presents a currently evolving hybrid research, teaching and public engagement methodology that uses game design principles and elements to overcome established limitations of participatory research methodologies and pedagogies (such as lack of transferability of findings and difficulties in comparing outcomes and datasets) through the inclusion of game design elements and a focus on systems thinking. Game design is inherently rooted in systems thinking, which has been highlighted a key competence in addressing the "wicked" problems and Sustainable Development Goals, a linkage which is still weakly explored by research. The paper will discuss the methodology's theoretical groundings and inspirations, with a particular focus on linking participatory approaches, game design and Donella Meadows's work on "Leverage Points" for systems-oriented interventions. The paper will then discuss how the methodology builds on and moves beyond established community mapping approaches by working with participants to progressively and co-creatively add more formalised game-like elements and dynamics (simulation, goal-setting, player-mapping, turn-taking, role-playing) that organically scaffold participants in moving towards more abstract systems modelling. Following an articulation of the process and its underlying theoretical framework, the paper will also present brief, reflective accounts of a number of experiments in playful participatory community mapping facilitated over a 18-month period, with diverse groups of participants across different countries engaging with the methodology and informing its evolution. These accounts will showcase how the game design lens has allowed participant communities to develop systems thinking and engage in systems mapping, moving from materially grounded and culturally relevant categories towards more systematised models, which include possible, practical "leverage points" for intervention. The paper will reflect on the process and the outcomes of these engagements, and on their influence in further developing the methodology itself, showcasing the potential of playfulness and gamefulness as powerful bridges between thinking locally and acting globally.

Keywords: systems thinking, co-creation, game-based learning, workshop.

1. Context & Inspiration

In the last decade, the debate about the societal role of universities in globalized societies has itself taken a very gamelike form, emphasising mainly competitive "games". League tables, marketisation and human capital theory have framed higher education (HE) as a positional good for both nations and individuals, assumed to enable them to acquire a competitive advantage on the global market, individual "players" trying to win competitive games (Marginson, 2004; Morini, 2020; Morini, 2021). This framing forecloses the autonomy of learners in these competitive games that they have not designed, and therefore the development of a pluralistic but shared sense of planetary citizenship (Fornasa & Morini, 2012; Kern & Morin, 2014; Moraes & Almeida Freire, 2016), defined as critical, active, and reflective participation in the complex entanglements of planet-wide socio-economic and ecological systems. This article argues that we need to envision and play different games to survive our current crises, and that we might as well do it literally by taking the active stance of game co-creators, both requiring and scaffolding the development of systems thinking.

Systems thinking is, within the context of this article, defined as the capability to collectively analyse complex systems across different domains (society, environment, economy, culture, health) and different scales (local to

global), considering cascading effects, feedback loops, emergence and other systemic features (Dubberly, 2014). Systems thinking's influence on learner participation in action-orientated change remains under-explored in educational research and is still broadly unaddressed in HE curricula (Benson, 2007; Feldmann-Jensen et al., 2019), despite having been increasingly highlighted as a necessary form of literacy (beside reading/writing, numeracy, digital literacy) to enable learners to meaningfully understand and respond to the interconnection of local and global crises (UNESCO, 2017).

The proposed approach, still in development and tentatively named YOUTHOPIAS (Youth Organising Through Playful and Participatory International Action Research and Systems thinking) aims at exploring how local and global systemic dynamics can be fruitfully problematised through playful approaches to teaching and learning, to promote the systems thinking required to build the sustainable and inclusive social ecosystems. YOUTHOPIAS is inspired by ambitious conceptual and practical experimentations in systems thinking from the '60s and '70s, such as Stafford Beer's CyberSyn project (a decentralised control system for the Chilean economy; see Espejo, 2014), Buckminster Fuller's World Game™ (a simulation built to anticipate and address global logistical scenarios; Fuller,1969) and Howard Odum's Macroscope (a set of conceptual tools, methods and techniques by which to understand very large systems – conceptually mirroring the microscope; see Odum, 1971).

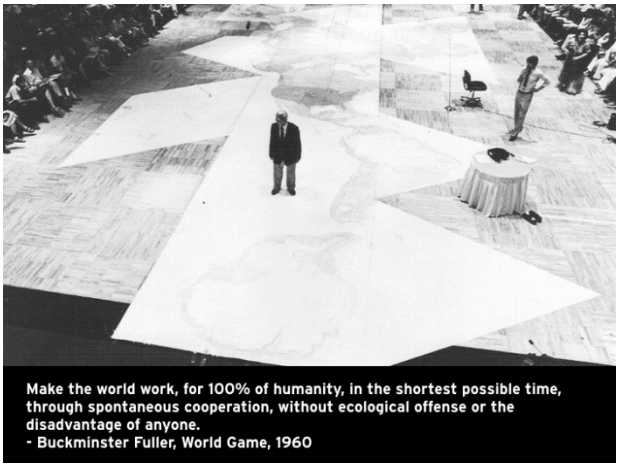


Figure1: Fullers's World Game

All of the above were attempts to make large systems readable and open to democratic organising, attempts which fell short due to both historical contingencies and methodological shortcomings, notably an assumption that the expertise to address those challenges is mainly located in (and owned by) academia and/or central governing bodies. The paper instead articulates the exploration of a more grassroots paradigm of HE research-intervention, using participatory, co-creative, culturally relevant, and playful pedagogies under the principle of systems thinking. YOUTHOPIAS moves therefore beyond those inspirations by leveraging 21st Century sensibilities and developments in intercultural education, in the methodologies of the social sciences, and in the design disciplines. On a practical level, this involved a pilot series of hybrid workshops held with local co-facilitators across Brazil, Malaysia and UK, engaging university students from plural disciplines (informing the intended transdisciplinary scope) and local youth, with the purpose to further develop the methodology through joint reflection on the co-created artefacts and on participants' engagement.

2. Systems Thinking and Games

YOUTHOPIAS explores the opportunities provided by the medium of play and games for engagement with systems thinking through design and cocreation (Gee, 2006; Zimmerman, 2008; Ito et al., 2010; Morini, 2013). In itself, the emphasis on the educational value of game co-design is part of a growing literature (e.g., Kangas, 2010; Kafai & Peppler, 2011; Arnab, Clarke & Morini, 2019), but still represents a relatively secondary perspective in the discourse of game-based learning, and one which we intend to re-centre here. YOUTHOPIAS in fact moves beyond a broad emphasis on co-design, emphasising the tension and interplay between two central aspects reflecting the useful dualism that the English language articulates between "play" and "game":

- The idea of "play" places the player's autonomy at the centre (albeit in a relational dimension with other players and the game itself), as articulated by De Koven (2013). The emphasis on "play" (often sidelined in the game-based learning literature) therefore translates into an emphasis on conceptualisation, modification ("modding"; Sotamaa, 2010) and co-construction of games as social and cultural activities.

- The idea of "game", on the other hand, emphasizes the examination of the formal elements that make up a playful artefact or activity: rules, information, objectives, mechanics, feedback. In particular, focusing on the “game” aspect allows participants to explore the conceptualisation, modification and construction of formal systems.

The first aspect, that of play / socialization / culture, is particularly important when co-design is carried out in communities marginalised on a socio-economic and cultural level, and where cultural relevance (Ladson-Billings, 1995) becomes central. Maintaining an element of freeform playfulness ensures a meaningful and rooted involvement in local needs and perceptions. The literature in this area is still limited but growing, and it is important to highlight how many contributions come from communities with a strong history of colonial subordination (LaPensée, 2019; Minoi et al , 2019; Miner, 2022), possibly as a result of having directly experienced being forced to follow rules and objectives imposed from outside (see Oliveira Andreotti et al., 2015, exemplifying different conceptualizations of coloniality in terms of rigged, harmful or meaningless games). The second aspect, explicitly linking games and systemic thinking, is still largely unexplored in current literature (some exceptions are Zimmerman, 2008; Young, 2016; Akcaoglu & Green, 2019) despite the fact that systems thinking is recognized as a fundamental requirement in the design of games of any genre (Tekinbas & Zimmerman, 2003). In order to synthetically articulate the generative connections between systemic thinking and playful/gameful thinking, a useful conceptual model is that of the "Leverage Points" for systemic change, proposed by Donella Meadows (1999), then more explicitly conceptualized in a playful way together with Sweeney and Meher (2010).

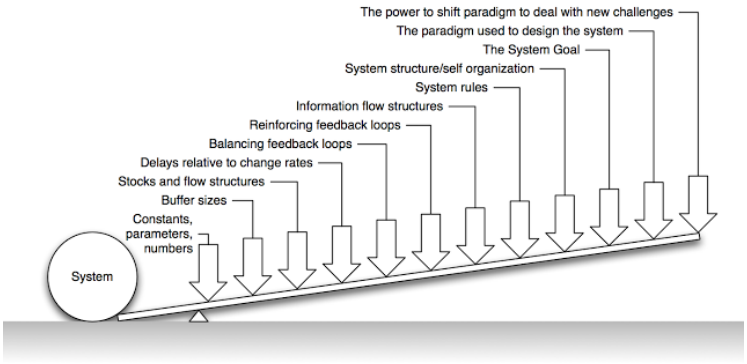


Figure 2: Meadows’s Leverage Points

In light of the previous arguments, it can be seen that most "leverage points" (feedback loops, information flows, rules, objectives, design) can be conceptualized in terms of key formal elements of a game co-design process, thus outlining a useful parallelism between the design / modification of play systems and the design / modification of ecological and social systems, while recognizing the important distinction between closed (playful) and open (socio-ecological) systems. As highlighted by other authors (Monat & Gannon, 2015), the exercises proposed by Meadows and co-authors, while representing a vivid example of the potential of this approach, remain extremely simplistic, mostly confined to a non-formalised and narrative level. This is probably due to a lack of familiarity of the authors with the modern developments of the medium, and therefore a lack of gaming literacy (Zimmerman, 2008). A deeper and more active involvement in the above-mentioned formal elements of game design allows, vice versa, to better appreciate the quantitative and counterintuitive aspects of systems behaviour.

As Pedercini (2017) argued, to co-create games is to think systematically about a problem. In urban studies, games including Monopoly and Sim City have achieved enduring popularity as entertainment and as educational tools (Schrier, 2021). Games such as Bay Area City Planner (Twu, 2015) and MultipliCity (Molleindustria, 2014) demonstrated the potential to engage communities in accessible and scalable discussions about their lived environment through tangible, simplified models of experiential scenarios, and informed YOUTHOPIAS choice to focus on engaging urban audiences. However, all the existing co-creation research and initiatives are centred around specific local communities, a missed powerful opportunity when the inherently systemic character of the game medium would be a privileged access point to initiate more abstract and comparative conversation about systemic dynamics.

These aspects, together, point at YOUTHOPIAS's core aim: to provide a blueprint for HE activities centred on planetary citizenship, community engagement and systems thinking, exemplifying an alternative way to conduct the three traditional core missions of education, research and societal engagement.

3. Developing a Methodology

Having outlined the broader theoretical background of YOUTHOPIAS, we will now outline some practical experiences informing its ongoing development. In the course of pilot hybrid workshops conducted before and after the critical phase of the pandemic, iterative versions of the YOUTHOPIAS approach have been used in collaboration with youth, students and academics in plural contexts and disciplines (newly arrived foreign youth, emergency management masters students and conflict resolution researchers in England; postgraduate students and teachers in sociology and educational sciences in Malaysia; students of a technical-tourism high school institute in Brazil).

The general methodological ethos of YOUTHOPIAS draws variously from Theatre of the Oppressed (Boal, 2013; Frasca, 2001), game design patterns and pedagogies (Bjork & Holopainen, 2002; Wanick & Bitelo, 2020), remix (Markham, 2016; Arnab et al., 2017) and speculative design (Mitrovic et al., 2021), with participants being facilitated towards creatively "playing out" local conflicts and concerns, and creating tangible models accessible to those unfamiliar with the specific context, conveying abstracted but culturally and experientially grounded models of local experiences and scenarios. Each instance of the process lasts ~2 hours and has 2 distinct phases (followed by a debriefing). The pilot workshops were facilitated over an 18-month period, with the main outputs being the co-created artefacts themselves and reflections generated by facilitators based on their experience of the workshop and interactions with participants. The article will now discuss the process in detail with examples and reflections from the workshops.

3.1 Participatory Mapping – Drawing the Board

In the first phase, participants are provided with simple "Do-It-Yourself" materials (Knobel & Lankshear, 2010) such as stationery and board game bits (e.g., playing cards, dice, meeples) when working in a physical space, or a templated online whiteboard. Participants are then supported to work in small groups (~5-6 people) and sketch playful maps of a known context (for example one's city, community or home institution), with an emphasis on what makes (or could make) it welcoming. Focus is on the context, and no personal information is collected, therefore complying with GDPR standards. This phase of the workshops is informed by literature around participatory mapping, an established approach in Participatory Action Research (Saija & Pappalardo, 2018) to generate shared community-based baseline understandings of the context, making tacit and subjective local knowledge visible and tangible – and therefore easier to discuss and reflect upon. In effect, participants are asked to draw a shared board to play upon in the following phase.

In this step the social/cultural aspect of play dominates, and the maps generated reflect a pluralism of interpretation of both urban environments and welcoming qualities, but also common, cross-cultural patterns of understanding: conviviality (e.g., areas with preferred food venues, green spaces and playgrounds), housing (articulating the plurality, and inequality, of urban housing planning) and movement (e.g., patterns of public transportation and accessibility).





Figure 3: Example boards generated by participants

While this phase has always proved fruitful in its open-endedness, participants were often reluctant to be creative using the materials at hand (often linked to claims of "not being able to draw"), and could broadly be linked to a reluctance of adults and young adults to engage in more freeform and creative forms of play (see Walsh, 2019, for a critical reading of this dynamic), and struggled to initiate the mapping. Invariably, as you can see by the examples above, this reluctance was overcome and the board colourfully populated. However, overcoming this reluctance often ate into the limited time allocated for the workshop and required strong scaffolding, which was much easier to provide in face-to-face iterations.

In future iterations we will therefore experiment with providing enhanced scaffolding for this phase, e.g., by providing pre-made common environmental "building blocks" through physical and digital post-its (drawing inspiration the widespread board game Carcassonne, or Pedercini's MultipliCity) based on the common recurring themes mentioned above. This is not to bind participants' contributions within pre-established boundaries, but rather to provide a starting point of reference, particularly when conducting the workshop online.

3.2 Players Analysis – Mobilising the Stakeholders

The second phase is where the formal, systemic game aspect moves to the forefront. Facilitating this transition, in the context of YOUTHOPIAS, means introducing a very basic system of simulated conflict, a key element of formal games (Tekinbas & Zimmerman, 2004 - though it's important to highlight how conflict doesn't need to be between the players/co-creators, but rather might be with or between elements of the designed system itself, and "victory" might mean addressing a conflict rather than winning it).

This transition is scaffolded by utilising a basic stakeholder analysis tool (Reed et al., 2009), with participants facilitated in mapping possible stakeholders for their board along two axes: influence and support. Recurring examples of stakeholders were local administrations and educational leadership (on the "influential but not necessarily interested" side) and conspiracy theorists and NGOs (often mapped as "opponents" in terms of conflicting interests but both lacking real influence). Having established the key "players" of the scenario (with the instruction of trying to have at least an example for each of the quadrants, and one for each of the participants in the group), participants are then facilitated in considering how their interaction might play out.

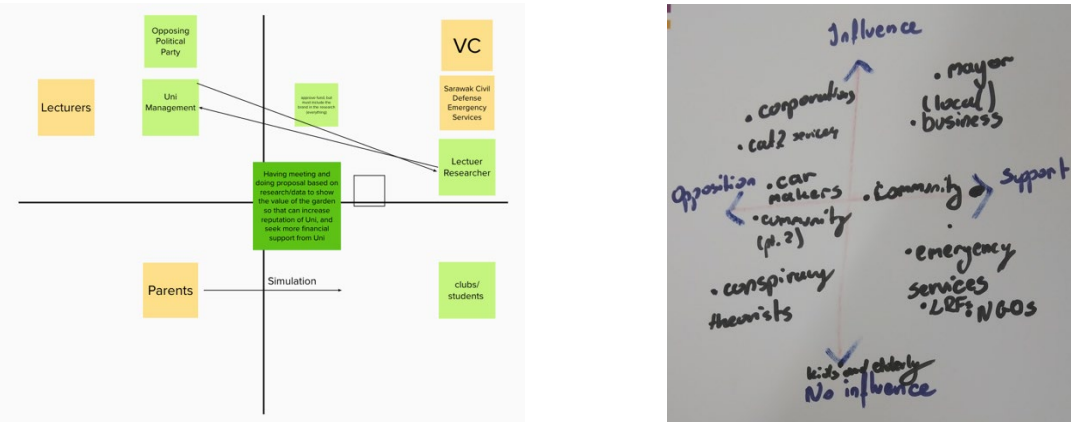


Figure 4: Examples of Players Analysis

To do this in a structured way, participants are asked to collaboratively establish an overarching, desired systemic goal for each of those "players" (e.g., being re-elected, improving business revenue, raising the quality of local schools, or preserving green spaces). In the latest iterations of the workshop, further emphasis was brought on formalising other systemic aspects, by facilitating discussion of other key systemic leverage points, in particular rules (e.g., regulations or institutional missions), and relevant feedback loops (e.g., votes and power; funding and organising capacity). Participants then are asked to take turns (an extremely common and cross-cultural game mechanic; see Elias, Garfield & Gutschera, 2012), choosing any one of the stakeholders, and considering and role-playing one of the following moves:

1. how a specific stakeholder might decide to make changes on the map, within the scope of their influence and interests (e.g., a public administration imposing regulations; businesses finding new markets).
2. how a stakeholder might decide to influence and shift the interests and influence of another stakeholder, particularly by acting on their desired systemic goals and feedback loops (e.g., students running an event to convince parents of the need for a change; citizens putting pressure on elected officials to support or oppose a certain outcome; NGOs fundraising to acquire more influence).

It's important to highlight the instruction for participants not to take a specific, chosen once-for-all role. This allowed them to play their evolving game-like model not as competitors, but rather maintaining a stance of co-designers of the system, and therefore in touch with the 2nd to highest leverage point proposed by Meadows: directly engaging with designing the system.

These constrained narrative interactions between "players" with different desired systemic goals, grounded in the shared narrative landscape of the board created in the first phase, and structured by the back-and-forth of stakeholders and turns, allowed participants to experience first-hand the dynamics of feedback loops, and through them the inherent systemic complexity of social interactions. Of particular relevance was how some of the narrated emerging interactions (e.g., the consequences of perverse incentives in academic careers; or cycles of gentrification generated by urban student housing) surprised even the participants themselves, who hadn't thought about some side effects of desired systemic goals, rules or feedback loops before being able to "play them out" on the shared board. This highlights the centrality of emergence in systemic understanding, and problematises assumptions of simple and linear causality often deeply embedded in non-systems oriented approaches to both education and research (Bateson, 1979; Oliveira, 2013).

As with the first phase, the open-ended nature of the task proved to be daunting at first, particularly for participants with less established links to the broader context (e.g., the newly arrived youth in the England site), which at times led to simplistic representations of the "players", their desired systemic goals and their roles within the broader board. Critically reflecting on this informed the progressive addition of further scaffolding based on explicitly addressing more of Meadows's leverage points, adding at the same time complexity in the outputs and anchoring starting points for the participants.

Following this and further feedback from participants and co-facilitators, future iterations of the workshop will involve participants building a simple, narrative "character sheet" for the "players" (see Clarke et al., 2018, for a similar technique within the context of learner self-reflection), to provide additional structured scaffolding and documentation, and importantly will emphasise the need to consider possible non-human stakeholders (e.g.,

local water systems or fauna; Leino, Karrpi & Jokinen, 2017) as integral part of ecologically sound systemic mapping.

4. What's the next game? Reflections and Next Steps

Although the playful models co-designed during the workshops cannot be defined as full and finished games (also due to time factors - game design is an iterative process which cannot be solved within the ~2 hours of the workshop; Kultima, 2015), the YOUTHOPIAS workshop, and its hybridisation of participatory mapping, role-playing and game design, nevertheless offered to participants the opportunity to experience themselves as active creators – not just passive subjects of someone else's model, but co-designers and critical reviewers of a shared model, and indeed of the paradigm used to generate it. The key element is therefore autonomy (literally "to give oneself one's own rules" - making the philosophical connection with games very clear), both of learners (in a humanizing and citizenship sense) and of educational processes in the broadest sense (freeing them from the competitive logics discussed in the introduction), touching the most powerful of Meadows's leverage points: the power (and indeed the necessity) to shift paradigm to deal with new challenges.

Coherently, the pilot series of YOUTHOPIAS workshops discussed above emphasised experimentation and playfulness with regards to the methodology itself, inviting open critique and conversations, and highlighted important shortcomings and ideas for further development. Some of those more closely related to scaffolding specific activities have already been discussed, but some of them stand on a more overarching level. The two most relevant, within the scope of promoting systems thinking, are 1) the necessity of developing and integrating in the workshop an explicit linkage with global systemic dynamics, and 2) the necessity to explore more accessible ways to invite broader participation from local communities and benefit local development.

To address the above, future iterations of the methodology will involve Collaborative Online International Learning (COIL) approaches as a space/place for the shared interaction of knowledge, ideas and theories from multiple cultural contexts (Rubin & Guth, 2015; Wimpenny & Orsini-Jones, 2020). This can be done, on a practical level, by using the shared process and the models created to more easily share the respective visions of local citizenship and societal participation developed in each local community, with local participants working as "play-testers" for each other, promoting perspective-taking through games (Dishon & Kafai, 2020) and meaningful intercultural communication and conversations.

A particularly interesting suggestion was also that of flipping the approach: why start small, when we could ask different communities to use the same approach to imagine whole "preferable worlds" (Dunne & Raby, 2013), and deploy both the playful/cultural and game-like/systemic aspect of YOUTHOPIAS to transfer those larger insights to the local level? While this might prove challenging in terms of focusing engagement and maintaining cultural relevance, particularly in terms of reaching out to local communities, it's surely something that will be experimented with.

The further developments of YOUTHOPIAS following the pilot workshops promise therefore to be both complex and challenging, but also offer a glimpse of the potential for systems thinking to scaffold a deeper linkage between thinking globally and acting locally – grounded through playful co-creation and generating a reflective feedback loop between university, society, and planetary systems. The piloting purpose of the workshops, while still acknowledging the need for further development, can therefore be considered achieved, showcasing the potential to advance beyond previous discipline specific (Young, 2018), less formalised (Meadows, Sweeney & Mehers, 2016) and digitally focused (Akcaoglu & Green, 2019) approaches.

To conclude, it's important to highlight the participants' strong, positive response in terms of participation and investment in the principle of material and cultural autonomy that we intend to put again at the centre of HE, in a form of inversion of many instrumental uses of education in general and game-based learning in particular. we argue here that, as both educators and citizens, we need to avoid using games instrumentally to bring into education the competitive and disempowering, game-like ideologies of reality. Vice versa we need to work through and beyond broader education systems to frame playfulness and imagination as powerful ways to maintain an active relationship with reality (Rodari, 2001).

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How to get the girls Gaming: A Literature Study on Inclusive Design

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Abstract: Gaming is a ubiquitous activity today where many children spend considerable amounts of time playing various games. Serious games have also become a mainstream educational tool in a wide variety of school subjects. Despite this, many games still have a design that mainly appeals to boys where girls are less frequent players. The aim of this study was to gather requirements for a design of serious games where girls should not feel excluded. The research question to answer was: *"Which design concepts are important if girls should be engaged in serious gaming?"*. Furthermore, the results from this study could be useful for future implementations of educational games. This study strives to address the research gap in the field of inclusive game design, and to gather important requirements for games where girls and boys want to play together. This study was carried out as a scoping literature review to map literature in the field of game design to identify key concepts that can attract the younger girl audience. Scoping literature reviews offer a method of mapping key concepts in a research field to identifying the main sources and types of evidence available. A central aim of a scoping literature review is to synthesise research results to a specific target group as a foundation for future research. For this study, the future research will consist of implementing the found design factors in an educational game on computer science. Findings indicate that there are specific game design concepts that girls find appealing. Important main themes to consider are Creativity and customisation, Character diversity, Collaborative interaction, and Exploration without violence. However, there seems to be several challenges related to the concept of designing specific girl games. The conclusion from this study is rather to choose a more inclusive game design where girls and boys would like to play together. A concept for game design that could be described as having a low threshold, wide walls and a high ceiling. The recommendation for a girl inclusive design is to carefully consider factors such as narration, backstory, social interaction, game graphics, sound design, and personalisation.

Keywords: Game design, Inclusive design, Games and girls, Game-based learning, Scoping review

1. Introduction

Games and game-based learning have been around for thousands of years, long before the appearance of digital video games (Hellerstedt & Mozelius, 2019). After the so-called casual revolution (Juul, 2010), gaming is a ubiquitous activity today in a larger target group than ever. Many children spend considerable amounts of time playing various types of games. At the same time serious games for educational purposes have become a mainstream teaching and learning activity in a wide variety of school subjects (Moreno-Ger et al., 2014), with game-based learning for students with special needs as an emerging research field (Hersh & Leporini, 2018).

However, as highlighted by Casell and Jenkins (2003), Carr (2007), and Lima and Gouveia (2020, girls and women have refused to embrace videogames with the same passion, and to the same extent as boys and men. Moreover, there are also research studies indicating that certain types of games are more appealing to a female audience than others, and that there are game design elements that better should be avoided (Subrahmanyam & Greenfield, 1998; Cunningham, 2018). Moreover, several research studies have identified that certain types of gameplay appeal more to boys than to girls (Subrahmanyam & Greenfield, 1998; Dilmaghani, 2022). However, there still seems to be a research gap to address regarding the more concrete game design. For an improved future game development, it is important to identify which game design concepts that could attract more girls to use serious games in educational contexts. Authors hope that the design factors found in this study should be useful in the implementation of games with a more inclusive design. The aim of this study was to gather requirements for a design of serious games where girls should not feel excluded. The research question to answer was: *"Which design concepts are important if girls should be engaged in serious gaming?"*.

2. Method

This study was carried out as a scoping review to provide an overview of the studied topic (Munn et al., 2018). The scoping review can be an appropriate approach to use when the studied topic is complex or heterogeneous (Pham et al., 2014; Mays, Roberts & Popay, 2001), and in studies with an aim of clarifying concepts and

identifying knowledge gaps. Moreover, his kind of literature review offers a method of finding key concepts in a specific research field, and to identify the main sources and types of evidence available (Munn et al., 2018). A central aim of this scoping review was to synthesise research results to a specific target group as a foundation for future research. The findings from this study will be used as a part of the design requirements in a future game development. Considering the aim, and the type of literature review the research question was formulated concrete and specifically to support this research design. Despite the narrow and specific research design, authors find the results from this literature review also could add a more general knowledge, useful for future implementations of educational games.

Google scholar was used as the main search engine to identify research papers of interest. With the use of Boolean operators OR and AND, keywords such as *Games*, *Inclusive*, *Design*, *Girls, Women* were combined in the search. Backward and forward searches were also used to identify additional research papers of interest. The scoping review was carried out in combination with a thematic analysis (Braun & Clarke, 2012) with an abductive process of analysis to move between deductive and inductive coding (Graneheim, Lindgren & Lundman, 2017). That is, the selection of research papers to include in the study was conducted in parallel with the analysis and no predetermined categories were used for analysis. Papers of interest were analysed immediately and identified themes were collected in a text document. The collected themes were organised, and reorganised, in categories as the analysis proceeded, with each new paper and identified theme either adding to the categories, creating new categories, or re-organising categories. Lastly, all themes and categories were revised for consistency and definitions of categories where formulated.

23 research papers, that are published between 1994 and 2021, were selected and analysed in the study (Table 1).

Table 1: Summary of included papers

Author(s)	Year	Title	Published in
Kafai, Y. B.	1994	Minds in play: computer game design as a context for children's learning	Hillsdale, N.J.: Lawrence Erlbaum Associates
Miller, L., Chaika, M., & Groppe, L.	1996	Girls' preferences in software design: Insights from a focus group	Interpersonal Computing and Technology
Kafai, Y. B.	1996	Gender differences in children's constructions of video games	P. M. Greenfield & R. R. Cocking (Eds.), Interacting with video. Norwood, NJ: Ablex Publishing Corporation
Rubin, A., Murray, M., O'Neil, K. & Ashley, J.	1997	What kinds of educational computer games would girls like?	AERA Presentation, April, 1997
Vail, K.	1997	Software companies are targeting girls, but is their marketing on the mark	Electronic School
De Castell, S., & Bryson, M.	1998	Retooling play: Dystopia, dysphoria, and difference	From Barbie to Mortal Kombat: gender and computer games
Graner Ray, S. G.	2004	Gender inclusive game design. Expanding the market	Hingham, MA: Charles River Media
Carr, D.	2005	Contexts, gaming pleasures, and gendered preferences	Simulation & gaming
Dickey, M. D.	2006	Girl gamers: The controversy of girl games and the relevance of female-oriented game design for instructional design	British journal of educational technology
Carr, D.	2007	Contexts, pleasures, and preferences: Girls playing computer games	Weber S., Dixon S. (eds) Growing Up Online. Palgrave Macmillan, New York
Dondlinger, M. J.	2007	Educational video game design: A review of the literature	Journal of applied educational technology
Fullerton, T., Fron, J., Pearce, C., & Morie, J.	2008	Getting girls into the game: Towards a 'virtuous cycle'	Beyond Barbie and Mortal Kombat: New perspectives on gender and gaming
Kinzie, M. B., & Joseph, D. R.	2008	Gender differences in game activity preferences of middle school children: implications for educational game design	Educational Technology Research and Development

Author(s)	Year	Title	Published in
Ioannidou, A., Repenning, A., & Webb, D. C.	2009	AgentCubes: Incremental 3D end-user development	Journal of Visual Languages & Computing
Vermeulen, L., Van Looy, J., Courtois, C., & De Grove, F.	2011	Girls will be girls: a study into differences in game design preferences across gender and player types	Under the mask: perspectives on the gamer conference 2011
Kafai, Y. B., & Burke, Q.	2014	Beyond game design for broadening participation: Building new clubhouses of computing for girls	GenderIT 2014
AlSulaiman, S., & Horn, M. S.	2015	Peter the Fashionista? Computer Programming Games and Gender Oriented Cultural Forms	Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play
Alserri, S. A., Zin, N. A. M., & Wook, T. S. M. T.	2017	Gender-based engagement model for designing serious games	2017 6th International Conference on Electrical Engineering and Informatics (ICEEI)
Çakır, N. A., Gass, A., Foster, A., & Lee, F. J.	2017	Development of a game-design workshop to promote young girls' interest towards computing through identity exploration	Computers & Education
Spangenberger, P., Kapp, F., Kruse, L., Hartmann, M., & Narciss, S.	2018	Can a serious game attract girls to technology professions?	International Journal of Gender, Science and Technology
Spieler, B., & Slany, W.	2018	Game development-based learning experience: Gender differences in game design	Proceedings of the 12th European Conference on Games Based Learning
Leonhardt, M., & Overå, S.	2021	Are There Differences in Video Gaming and Use of Social Media among Boys and Girls?—A Mixed Methods Approach	International Journal of Environmental Research and Public Health
Sharma, K., Torrado, J. C., Gómez, J., & Jaccheri, L.	2021	Improving girls' perception of computer science as a viable career option through game playing and design: Lessons from a systematic literature review	Entertainment Computing
Dilmaghani, M.	2022	Chess girls don't cry: Gender composition of games and effort in competitions among the super-elite.	Journal of Economic Psychology, 89, p.102482.

3. Results and discussion

The scoping review identified five main themes in the reviewed literature. Four of the themes are considered important design concepts for engaging girls in serious games, while the last theme addresses potential problems in designing games specific for girls' motivation and engagement. The identified themes are presented under separate sub-headings here below.

3.1 Category1: Creativity and customisation

Girls have expressed a greater preference and more positive preferences for games that encourage creativity, where creativity could be encouraged by features for modifying game characters and game elements, or the possibility to create artwork for use within or outside the game (Kinzie & Joseph, 2008). It was also pointed out in the study by Spieler and Slany (2018) that female players spent much more time creating artwork than gathering game points, if compared to male players. Girls prefer to create, modify and to avoid the violent feedback that appears in combat games, while boys seem to choose the opposite (Kafai, 1996; Kafai & Burke, 2014). The study by Fullerton et al. (2008) recommends the possibility to change the world in games, and that players could have a positive impact on the surrounding society as well.

Sharma et al. (2021) highlighted that gaming girls appreciated functionality that enables them to customise components in the game environment. Something that helped the girls to express themselves and to demonstrate their preferences (Çakır et al., 2017) and that it was reported that girls became fully engaged in these activities (Ioannidou, Repenning & Webb, 2009). An example of a game with more of customisation and creativity than of actual gameplay is Sims games (Fullerton et al., 2008). Most of the games in the Sims series rather lack clearly defined game goals, and have been called digital doll houses. The Sims series, are game where

virtual characters get sad, moody and even depressed if they get isolated from other sims, and that there are concrete things to learn in Sims that could be useful in a player's daily life and work as found in Mozelius (2014).

3.2 Category2: Exploration without violence

One of the most obvious differences seems to be that boys are attracted to games with combat and violence, while girls prefer indirect competition without violence (Ray, 2003; Vermeulen et al., 2011). This difference has even more clearly been identified in studies on game creation, where the study by Spieler and Slany (2018) found that boys created significantly more shooter games while girls preferred to build role playing games. It has also been identified that girls have a stronger tendency to design games with a mix of male and female characters, with more options to choose different game avatars (Kafai, 1996). In this type of game creation studies there have also been reported that there are differences in the feedback design. Several research studies have reported about girls building games with little violence or punishing feedback, compared to boys that created features with violent feedback in fantasy settings (Kafai, 1996; Dickey, 2006; Kafai & Burke, 2014). In a recent study of Dilmaghani (2022), it was claimed that female chess elite players' approach to competitive chess is shaped by the belief that they have something to prove to males. A statement that origins from the Woman Grandmaster (WGM) Jennifer Shahade (2010), and her observations of the female chess elite. However, what goes for WGM Shade and other females in the chess elite, would probably differ from the attitudes among girls that do not play chess at elite level.

Instead of violence in the gameplay, girls want exploration, collaboration and challenge in a game design with more realistic adventures and activities in game environments with sophisticated graphic and sound design (Miller, Chaika & Groppe, 1996; Dickey, 2006). Other studies have pointed out that girls want an explorative gameplay with a rich narrative, diverse activities, engaging characters, and social interaction (De Castell & Bryson, 1998; Rubin et al., 1997). It could be argued that some of studies above were conducted over two decades ago, but the high percentage of violent games still remains. The balance seems better in the realm of serious games, where the design often is closer to the vision of the Johan Amos Comenius. The father of game-based learning propagated for a peaceful utopia where enlightened citizens living in harmony. Comenius's pedagogic works on game-based learning in the 17th century were developed around the idea of *"without violence, everything would flow spontaneously* " ("Omnia Sponte Fluant: Absit Violentia Rebus"). (Hellerstedt & Mozelius, 2018, p. 7)

3.3 Category3: Collaborative interaction

The various studies on children creating games reports that boys to a higher degree preferred to build competition and combat games, compared to girls that cared more for social interaction. In Kafai's (1994) landmark study on the gender differences in game design this was identified that girls created games with richer interaction, whereas boys tended to create games around the idea of combat. Miller, Chaika and Groppe (1996) found in their focus group discussions that girls prefer games with collaboration and challenge instead of combat. Other studies have highlighted that girls in general want a gameplay with social interaction built around a rich narrative and sophisticated game characters (De Castell & Bryson, 1998; Rubin, Murray, O'Neil & Ashley, 1997). As summarised by Dickey (2006, p. 78) *"There are many commonalities between most of the studies concerning female-oriented design, but the most notable is the importance placed on collaboration and community."*

One way of classifying games is by the division between combat games, competition games and collaboration games. Findings indicate that boys prefer combat games (Kafai, 1996; Spieler & Slany 2018), whereas girls fancy a game design that involves collaboration (Miller, Chaika & Groppe, 1996; Dickey, 2006). Competition seems to be more in-between, and as claimed in the study by Taylor (2003), games with competition appeals to girls when combined with collaboration. Back in the 17th century Comenius described how he wanted to combine his peaceful and serious gaming with both collaboration and competition to stimulate learning (Hellerstedt & Mozelius, 2018). As described by Demetriadis, Tsiatsos and Karakostas (2012), a 21st century concept to stimulate collaboration in serious games is to involve scripted collaboration. Collaboration scripts could be further divided into the sub-categories of Conflict scripts and Role-playing scripts (Mozelius, Borglund & Öberg, 2021). A hypothesis to test in future research is if boys tend to prefer Conflict scrips and girls prefer Role-playing scripts.

3.4 Category4: Character diversity

As pointed in the seminal studies by Kafai (1994; 1996), girls prefer a game design with both male and female characters, and that girls often creates games design for both male and female characters. Moreover, girls also like non-gender-specific characters in realistic settings (Kafai, 1994; Dickey, 2006). In the recent study by Leonhardt and Overå (2021, p. 7) it was reported that *"Both boys and girls were critical of gender representation in video games"*, and 25 years after Kafai's studies this unbalance seems to remain. As formulated by a 9th grade girl: *"The characters in video games are mostly guys. There are lots of war games. I don't play any video games where the main character is a man."*. This is a statement from a girl that described herself as having gaming as a hobby, but at the same time being reluctant to many video games because they lack *"good female characters"*. In the same study, another girl brought up the passive and helpless princess character in the Super Mario Bros games as an example of a bad female character (Leonhardt & Overå, 2021, p. 7).

Female role models are important, and as highlighted by Spangenberger et al. (2018), in a game with a female protagonist the girls' interest in technical subjects increased after playing the game. In a study on serious games for learning computer programming, two games were intentionally designed different. The first game was designed to be gender neutral, whereas the second had a girl-oriented design. Findings from the study indicated that the two games were equally effective regarding the learning outcomes, but that players with a preference for girl-oriented games got a stronger motivation to learn computer programming when they played the girl-oriented game. (AlSulaiman & Horn, 2015) This contradicts the findings in the study by Kafai (1994), where it was reported that girls prefer non-gender-specific characters. A contradiction that leads to the next category of 'Gender specific game design', and at the same time relates to Category 1, 'Creativity and customisation'. As pointed out by Sharma et al. (2021) in a study on design of serious games for girls learning about computer science, personalisation was one of the most desired design factors in the games. Moreover, it has been claimed that personalisation could motivate girls to see themselves as role models (Alserri, Zin & Wook, 2017; Sharma et al., 2021). Might customisation and personalisation be a key concept for inclusive design, and in more aspects than the one of gender?

3.5 Category5: Gender specific game design

Previous research has noted that the challenge of getting more girls and women into games and game design could be addressed through gender specific design, a so called "virtuous cycle " (Fullerton et al., 2008). Girls and women may be more attracted to games and making games if there are more games that appeal to girls and women, resulting in more games that are created by girls and women (Fullerton et al., 2008). However, games that appeal to women and girls alone will not result in more female game designers. A game on designing dresses will probably appeal to many girls and women, but will likely not influence them in taking a career path as engineers (Dickey, 2006; Vail, 1997). Further, it may be advised to offer both girls and boys the opportunities to develop in areas that they normally would not be drawn towards. If given the opportunity to develop appropriate skills, girls and women may appreciate Strategic and Active gameplay; and boys and men may appreciate more creative gameplay (Kinzie & Joseph, 2008).

As expressed by Dondlinger (2007), the presumption that girls and women differ from boys and men in gaming habits, for example that it is not done with the same intensity and duration, has little empirical support in research. The potential problem of ascribing gaming preferences to gender is that it may hide the underlying structures that fuel these preferences:

> *"The problem with ascribing particular preferences directly or solely to player gender is that it implicitly divorces gaming tastes from the economic, social, and cultural forces that fuel and inform gaming practices."* (Carr, 2007)

Previous research has pointed out that the notion that girls and boys prefer different types of games may have more to do with exposure and marketing, rather than real preferences (Dondlinger, 2007; Carr, 2005). In a study by Carr (2005), it was observed that female players played the games that they knew about and was exposed to. A conclusion of this study was that gaming preferences have more to do with prior experiences and exposure, rather than gender specific game design (Carr, 2005). If exposed to games marketed towards boys and men, girls and women seem to enjoy them and play as aggressively (Dondlinger, 2007; Carr, 2005). An example of girls and women that appreciates both competition and combat can be found in the highly aggressive, but non-violent game of chess (Dilmaghani, 2022). At the same time, it is a well-reported fact that there are substantially fewer girls that participate in competitive chess (Chabris & Glickman, 2006; Barbier, A., 2020).

4. Conclusion

The conclusion is to choose an inclusive game design where girls and boys would appreciate to play together. This game design concept could be described as a game space with a low threshold, wide walls and a high ceiling with as few barriers as possible. A girl inclusive game design should consider factors such as narration, game characters, social interaction, game graphics, and sound design. This should also be complemented with features for customisation and personalisation of these factors. Findings that not only are important to authors' future game development, but also to the general knowledge base of inclusive game design.

5. Future Work

The findings from this study should be used as input to the requirement definition for a serious game that will be developed in the Erasmus+ Gaming4Coding project. In the future work with the game design the relationship between gender, gameplay, learning outcomes and learning theories should also be addressed. This study has the limitations of a scoping review, and for a more complete view of the state-of-the art in the field of gender aspects of game design, a systematic literature study is recommended.

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Systems Mapping to Support Interdisciplinary Understanding in Serious Game Design

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Abstract: This article discusses the advantages and limitations of systems mapping as a method of approaching serious game design on the highly complex social issue of Intimate Partner Violence (IPV) in an interdisciplinary team. The method of systems mapping has been evaluated for the research and design phase of a yet unfinished game. It has been shown to be useful as a tool for research, design and interdisciplinary collaboration. Systems mapping does not provide new knowledge in the respective research area nor does it offer direct solutions to difficult design problems, but it supports the process and makes it more structured and substantial.

Keywords: Systems Mapping, Serious Game Design, Intimate Partner Violence, Interdisciplinary Collaboration, Games for Social Change.

1. Introduction

This article discusses the advantages and limitations of systems mapping as a method of approaching serious game design on the highly complex social problem of intimate partner violence (IPV) in rural areas. As part of an ongoing, publicly funded, four-year interdisciplinary research project, we seek to develop, test and evaluate game based learning as an innovative way of primary prevention of IPV. Primary prevention aims to reach all members of civil society (especially in their roles of relatives, neighbours, friends, or work colleagues). We hypothesise that educational games have the potential to address a large number of people in order to improve empathy with victims of IPV, to understand the responsibility of perpetrators for their deeds and to promote support for survivors and affected children. Facing widespread knee-jerk reactions from outsiders, such as the question “Why doesn’t she leave?”, we see the need to educate about the complex interactions of the conditions behind domestic violence. Rather than addressing only the private problems of individuals or focusing on the act of violence itself, the game must address the deeply structural and long-term – even transgenerational – nature of the issue. Understanding this complexity also posed a first general challenge in our game design process, namely establishing a common ground of knowledge within the team. Another challenge was dealing with the different disciplines' approaches.

1.1 Motivation

Due to its complex nature, our educational game theme falls into the realm of games for social change. Inspired by the presentation of game practitioner and scholar Macklin’s presentation at the Games for Change festival (Macklin 2020), we started the game development with Systems Mapping as a method to visualise and understand the elements and complexity of the target domain to be addressed. Meadows and Wright (2008) refer to systems thinking as a "lens" for looking at the world and its problems. Understanding the behaviour of a system requires examining not only its elements, but more importantly its connections, which are often not directly observable. In systems mapping, the elements are depicted as "stocks", which are visualised as nodes that represent quantities of certain materials, values or information states. Nodes are connected by inflow and outflow arrows that link them to other nodes. These flow diagrams can form loops that illustrate either balancing or reinforcing system behaviour, which can explain why certain undesirable cross-system effects are too stable to be easily changed. Our hope was to see systemic interdependencies in the mapping process that would lead us to game ideas that could adequately represent the actual persistent problems.

The project team consists of different professional groups, such as game design and media pedagogy, as well as a group of IPV experts with a background in social work, political science, sociology and gender studies. With rough educational goals in mind (e.g. to create empathy with victims and to point out help hotlines), the aim was not to develop a formal model for a computational social simulation. Rather, we were looking for potential

influencing variables that could be incorporated into game elements and especially mechanics (such as, reward structures, winning strategies).

1.2 Application field of the serious game

Every fourth woman in Germany experiences sexual or/and physical violence by her (ex-) partner at least once in her lifetime (Schröttle and Müller 2004). Police crime statistics on Intimate Partner Violence show more than 148.000 reports with 79,1% male perpetrators for the year 2020 (BKA 2021). IPV is a social problem that occurs regardless of region, age, educational level, socio-economic status, ethnicity or sexual orientation. It has a high impact on the physical and psychological wellbeing of the victim as well as on children growing up in an environment of Intimate Partner Violence.

The focus of our project is on IPV in predominantly rural areas, as more than half the German population lives in rural communities. According to Völschow (2014), these areas have particular social features and factors related to local structures: scarce support resources, difficult-to-access intervention and counselling services, as well as a high tendency of victims and those around them to treat IPV as a taboo. Tightly knit, small communities, a lack of anonymity and the repercussions of increased social control for victims are reasons to play IPV down, or to fail to recognise it for what it is. Two main factors lead victims to stay in their abusive relationships: The fear of losing networks if they talk about the abuse and therefore keep the silence, and the lack of courageous intervention and support from those around them (Völschow and Janßen, 2016).

An extremely important factor in helping victims of violence against women and their children – especially in rural areas – is therefore to break the taboo and counteract the trivialisation of the problem. It is necessary to sensitise and activate a broad part of the civil society so that they become aware of IPV instead of ignoring it. To raise this awareness, our research project „In Jeopardy: New Ways of Prevention and Support in Case of Intimate Partner Violence (IPV) in Rural Areas“ seeks for innovative ways of primary prevention in a rural model region. The serious games designed in this context are embedded in a public relations campaign that aims to break the taboo surrounding IPV and sensitise adults and adolescents to this social problem.

1.3 Objectives

The focus of this article is a field report on the application of the systems mapping method with regard to the project's objective of developing game mechanics that can represent the interdependencies of the real problem. We are particularly interested in balancing and reinforcing factors of the social and structural conditions and effects of long-term IPV for victims, for communities and within society as a whole.

First, we explored the method as a way to transfer and accumulate knowledge from social sciences research on the subject matter into game design. At the same time, it served as a kind of translation aid between different disciplines, their differing idioms, logic, methods and methodologies, even mindsets. While the project is still ongoing, we present our approach with different steps of systems mapping, resulting in an abstracted map for the game system that will be a central part of the game mechanics. Beyond this success, we report on findings and experiences from the process and also highlight obstacles and limitations of the mapping method with regard to the interdisciplinary work between game design and the target domain, which is in the field of social work.

2. Related work

"Games are intrinsically systemic: all games can be understood as systems" (Salen and Zimmerman 2004). This insight is prevalent in almost every textbook and lecture on the foundations of game design. Salen and Zimmerman point out that there are differences between "open" cultural systems and "closed" formal systems like (digital) games, which are self-contained by their rules. By framing games as "experiential" systems, on the one hand the strategic game actions of players are only relevant internally within the closed game system, while on the other hand, their play is embedded in the emotional and social environment in which the game is set. With this in mind, we are aware that systems in our context are manifold. First, we are interested in understanding systemic dependencies that are unique to the social application domain in the real world. Second, we need to create a game system with a closed set of rules (the mechanics, apart from the also needed game narration), and third, the experience of that game has an educational goal. In this article, we explore the first two aspects, focusing on the method of systems mapping.

Systemic analyses of group behaviour and individual reasoning have already been carried out in the development of games with computational social interactions, for example in the social simulation "Prom Week" (McCoy et al. 2011). Based on a formal model called "social physics", players experience different situational reactions to their choices when communicating with characters. While the goal of this agent-based approach was entertainment and learning, computer-based simulations have long been used in the systems analysis branches of the social sciences for other purposes, such as prediction, proof or discovery (Axelrod, 2005). In contrast to these approaches, our modelling can be less formal. Our aim is not to simulate behaviour in a situation of violence or in an artificial society, but to understand the social context of the causes and ways out of IPV and to create awareness. In order to apply "systems thinking for social change", Stroh (2015) suggests to use the "Iceberg" metaphor (compare Figure 3) to distinguish perceivable symptoms above the surface from underlying root causes. Further, he underlines the difficulty to find effective leverage points in the deeper, structural areas of the Iceberg map that could lead to sustainable change. Sellers (2018) endorses systems mapping as an entry point to Game Design, but he also points out that designing systemic games may need to work from different directions, either top-down looking at the whole system or starting bottom-up from the parts. Game systems need to be balanced taking into account balancing and reinforcing loops. Colleen Macklin proposed systems mapping at the starting point of the creation of a game for change (Macklin, 2020), which inspired us to engage with it.

However, there is no linear path to derive educational success from a correctly analysed system. Game design is a holistic arbitrary process that requires creative decisions on mechanics, narrative details, feedback on game actions and options for player strategies. For example, the serious game "SPENT" (by Urban Ministries of Durham, https://playspent.org/) aims at raising awareness and empathy for people living in poverty. Similar to some aspects of our topic, persistent poverty is a systemic problem, but one that is attributed to individuals in the public perception and is associated with prejudice and the stigmatisation of those affected. The game SPENT's evaluation (Hernández-Ramos et al, 2019) shows that there can be unintended learning effects, although the design reproduces many systemic features. However, the player has the chance to "win" the game, which can reduce empathy with the "losers" in the game and in real life.

Previous work in the creation of serious games about IPV includes the following examples. The game "*Jesse*" was designed by the "None in Three" research centre for the global prevention of gender-based violence, to work against the apparent social acceptance of domestic violence in the Caribbean and to increase empathy. Evaluation shows that the participants, boys and girls, recorded a significant increase in affective responsiveness after one week of game exposure (Boduszek et al, 2019). "*Violent dad in child´s shoes. A moment before*" stimulates a perpetrator's situational awareness and empathy for a child victim of gender-based violence (Arcidiacona and Di Napoli, 2021). In a therapy setting based on Virtual Reality, offenders are confronted with their deeds. The game "*Diana frente al espejo*" (department of equality of Málaga city council in collaboration with the University of Málaga, https://dianafrentealespejo.com/) aims at enabling young people to recognise sexist and violent behaviour in a relationship. The web-based game "*Decisions that Matter*" (Carnegie Mellon University, http://decisions-that-matter.com/) is intended to raise awareness about sexual assault in the university environment,focusing on the role of the bystander. Concluding, it can be stated that the goals of the previous games (in general) lie in the cautious sensitisation to problems, and the topic is probably hardly suitable for competitive games. For the German context and language, there is no comparable serious game on the topic so far.

3. Approach

In the following, we describe our two approaches that made use of systems mapping. First, the visual mapping strategy was used in the context of accumulating domain knowledge, and second, it was used to discuss and negotiate a game system with the aim of creating game mechanics as part of the serious game design.

3.1 Systems mapping as a research tool

The game designers in the team were completely new to the social research domain, without any background knowledge of Intimate Partner Violence, an area of research that spans 40 years of empirical findings. One of the first tasks in the whole project was to exchange at least sufficient information with the domain experts, before first drafts of game design could start, especially with regard to the specifics of the addressed rural area, and the importance of primary prevention in general. Also for the IPV experts in the research team, it was necessary to systemise and "condense" the whole field in order to focus on specific parts, such as reinforcing

factors for the persistence of taboos, the individualisation of the social problem, and the observed lack of community willingness to support survivors.

For the acquisition of knowledge, the game designers consulted literature, from which they created “mini maps” on different parts of the general topic, e.g. knowledge components about dependencies and reasons that keep battered women in an abusive relationship (emotional, financial, social reasons and more). Other mini maps covered findings about possible strategies, resources needed, and ways out of an abusive relationship, or typical phases of contact in which bystanders have different options for help (e.g. Brzank, 2012; Johnson, 2008; Kidder, 2006; Schröttle and Ansorge, 2009; Stark, 2007). In addition to literature, the rich experiences of a team member's practical social work contributed to parts of the maps, which helped illustrate incidents by vivid examples.

The interdisciplinary research team used the online collaborative whiteboard tool “Miro” (https://miro.com) to create visual maps of the dependencies found in these sources. This work was possible entirely during online collaboration periods pertaining to the pandemic. The research and sources consulted mostly described their findings as assumed causal relationships between entities, or at least as likely influences between concepts. In addition, reports from the field (e.g., experiences from a battered women’s shelter) provided explanations with new connections to the items already existing in other maps. At this early stage in the process, it was easier to follow an approach of causal mapping than to recognize full system features. Thus, instead of maps with stocks and flow details, we mapped the discussed elements with arrows between entities that illustrate causative relationships, where positive vs. negative influence could be distinguished through green or red coloured arrows, or plus vs. minus signs. “Causal” here does not mean identifying a single causality or responsibility, but rather a collection of possible influences and explanations that entail the observations and form patterns of dependence (Sloman, 2015).

Because of many possible links from one theme to items in another one, we have combined the mini-maps into one large map representing all the material processed so far. Figure 1 illustrates the broad dimensions of possible overlapping connections between the different topics from literature and practical experience.

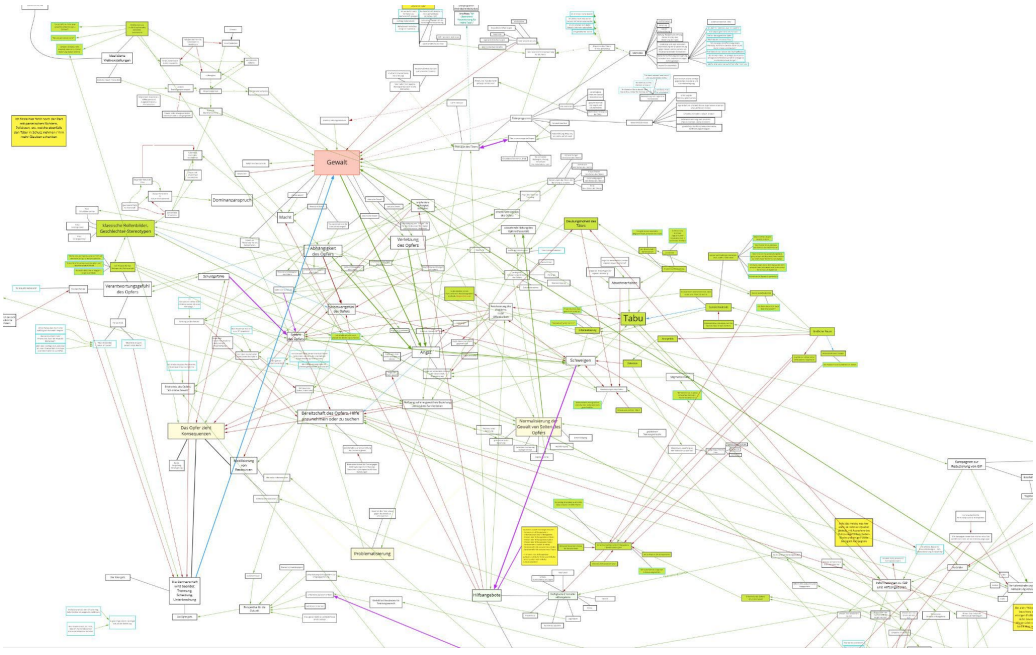


Figure 1: System map after the research phase: all aspects are connected, around a central concept of ‘violence’ in red

Parts of the maps point to repeating patterns, for example, to the cycle of abuse (Walker, 1979), or the deadlock created by the taboo against naming violence for what it is. Recognising the reinforcement loops within structures could help to get insights into these reasons. An example is shown in Figure 2. The taboo in the rural area leads to isolation of victims of violence who believe they are alone with this problem. This also affects their shame, which recursively silences them, reinforcing the taboo.

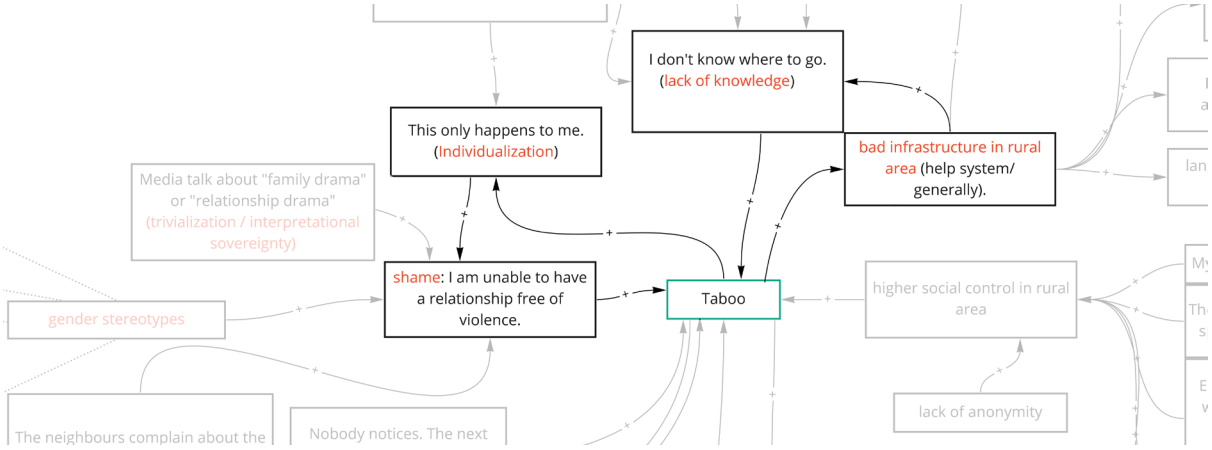


Figure 2: Example of a partial map (zoomed-in excerpt) around the key term “Taboo”

The attempt to better organise the elements in the map required a distinction between situational causes that affect individuals and more structural causes that allow the view of an abstract system. We ranked several of our map themes by placing them into an Iceberg model at different depths, according to their assumed structural aspects (see Figure 3). This helped us to discuss the potential leverage points for change, as a guide to find further themes and goals for our intended serious game.

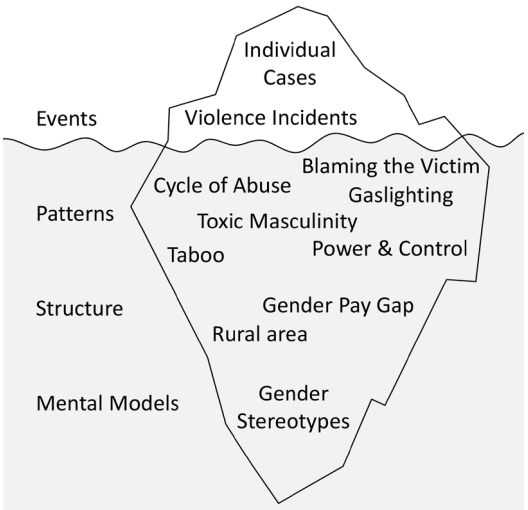


Figure 3: Sorting topics into the Iceberg model

In Figure 3, the aspects above the surface are possible situations that can be concretely depicted, e.g. how to intervene as a neighbour in an actual dispute or leaving an abusive relationship from the perspective of a victim. However, if we look beneath the surface, we find patterns and structures that are not so obvious to those who are not yet aware of this problem area. To understand why it is difficult to leave an abusive relationship, it is worth looking at the connections of IPV with gender stereotypes, or with structural aspects of typical women's occupations that lead to financial dependency, and much more. According to Stroh (2015), for sustainable change, it is necessary to find leverage points at deeper levels. However, since it is difficult and unlikely that e.g. gender stereotypes can be easily changed through an educational game, we decided to look mainly at the "patterns" level of the iceberg, which lies just below the surface. By learning names for phenomena such as "blaming the victim" or "gaslighting", players could learn to recognise these patterns when they occur in their environment.

3.2 Systems mapping as a design tool in an interdisciplinary team

We found that we could most effectively use the identified leverage points for a game if our topic appeals to bystanders (not victims or perpetrators) in terms of prevention. The premise is that they are generally responsive to the issue of IPV and willing to engage, but just do not have enough knowledge to do so. The instrumental goal is to enable them to recognise signs of an abusive relationship and get them to think about their own role in the IPV system and their potential contribution to improving it.

We could incorporate some of the dependencies of the IPV system into our game mechanics to convey its systemic aspects, as game mechanics can transport messages (Bogost, 2007). We developed guidelines on what messages we do not want to send with our game in order to avoid typical prejudices and stigmatisation related to IPV. One example is that we do not want to portray the victim as a helpless “damsel in distress” who needs to be rescued, but rather make their situation understandable and meet them at eye level. We want to illustrate that there are no easy solutions that fit every case, and therefore do not want to promote specific recipes for ending or reducing IPV as "ideal ways". We must avoid further stigmatising victims, justifying perpetrators, assigning responsibility for improvement to victims or confirming other harmful misconceptions about IPV.

The removal of taboos surrounding IPV is one major instrumental goal of the project. We identified social control through a supportive network as a leverage point to tackle the taboo. In the IPV system, there is a reinforcement loop between the taboo and the social control of a traditional network typical for a rural area, which leads to a fear of isolation or rejection by that network and (unintentionally) tends to support abusers. People just do not want to stand out and break the taboo, because nobody else does. There is also a balancing loop that is manifested in people reacting negatively to other people who nonetheless break the taboo.

Figure 4 shows our design result, with which we have tried to abstract this problem as much as possible. Below left, the reinforcement loop of the taboo runs in the traditional community of a toy village (as the “old” network). The players’ mission is to counter the fear of isolation and explore different ways of contributing to a "supportive" network rather than strengthening the "old" network. They also face the risk of rejection and consequences if they try to speak out against the "old" system. The goal is to raise the level of awareness in the toy village and thereby recruit new members for the new “supportive” network. If successful, the “fear” stock can be reduced and the processes mapped lead to another reinforcement loop (Figure 4, top part) that enables the new network.

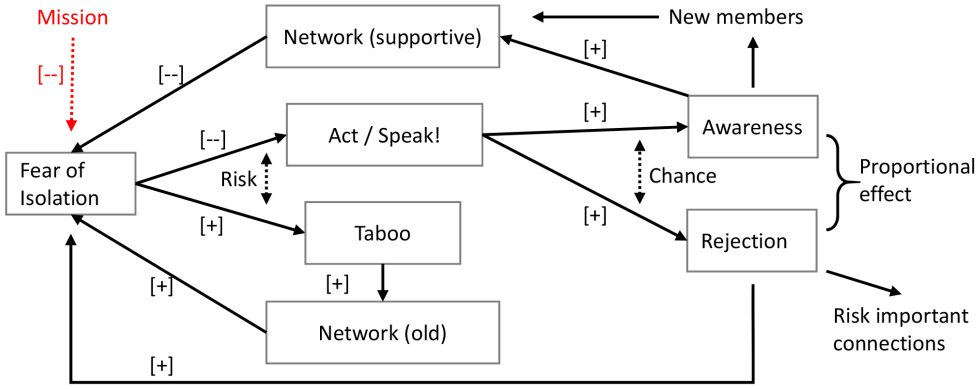


Figure 4: System map of the game about taboo reduction.

Our “taboo” mini map (see Figure 2) will serve as model content for the development of game narratives. Recent experiences of the “me too” debate show that if certain tipping points are reached, a discussion gets into the public awareness. The more people have yet broken the taboo, the easier it is to join.

This model describes IPV on an abstract level and provides the objective of the game. It also provides a framework for narratives to be filled with concrete events, incidents and vivid experiences. Based on the situations portrayed, players can immerse themselves in the problems. Depending on how far the players manage to expand the support network and what influence its members have, there are different epilogues at the end that tell what the future of the toy village will look like in terms of coping with domestic violence. Due to the simplicity of the mechanics, a sensitive and nuanced narrative will be an important factor for success.

4. Lessons learnt

In the following, we summarise our lessons learnt from the systems mapping exercise for our collaboration between the disciplines of game design and the diverse expertise from the social field.

4.1 Lessons from systems mapping for analysis

The main concern of the social work experts in the interdisciplinary collaboration was to incorporate the findings from 40 years of international research on IPV and the many years of experience of the help system for protection against violence into the game content. A comprehensive amount of knowledge needed to be imparted into the team in a short time, and the tool of systems mapping was very helpful to this end. The visualisation of literature sources used to map the topic of IPV supported the process in two ways. First, the mini maps depicted the essential findings of the papers, which therefore could be comprehended more quickly. Second, the addition of further sub maps worked as a protocol of the knowledge acquisition process. Misinterpretations could be easily detected, discussed and rearranged in the maps.

At the same time, the systems mapping approach was also experienced as mechanistic, which initially caused resistance and confusion among social work practitioners. The domain experts had not previously pursued social systems theory approaches, as their focus was clearly on the conception of solutions. The need for a rigid logic to find structures of cause and effect, combined with the attempt to clearly identify points of leverage and intervention, contradicted their usual approaches and seemed too deterministic. Ultimately, however, we assessed as a novel finding that the practice of these knowledge collections could potentially be transformed into a useful tool for professionals working in the field of protection from violence, as well as in training courses or as part of university education in social work sciences.

Also for the game designers, the process was not always straightforward. It was easiest to define the elements, while it was more difficult to define all the arrows with the logic direction, which led to an increased need for discussion.

4.2 Lessons from systems mapping for design

The game mechanics determine how the game system behaves and how it reacts to every possible action of the player. It is composed of calculations and clear conditions and can also be represented as a system map (Figure 4). However, it was not possible to simply derive this game map entirely from the system map created in the research. Most aspects are abstract phenomena that cannot be measured with numbers, such as "fear", so it is not clear from the system map how strongly the aspects influence each other. There are also no precise conditions. Even though the map shows typical influences and causalities, these describe possibilities rather than universal rules that can be applied in every situation. Many cases of IPV follow similar patterns, but they differ in the details of how these patterns develop and how they can be overcome.

To implement the digital game, designers must therefore draft the necessary values and conditions as they see fit. This means that the behaviour of the game system is the result of a creative process with fictional rules, even though it is based on the real world system known through established research. Some of the fictional processes underpin the message we want to convey, others are simply necessary for the game to work technically. However, players cannot distinguish between the two. We are aware of the risks that, as with the game SPENT, a divergent message may arise through the gameplay dynamics that are left to the player. It is the responsibility of game designers in the later design phase of game balancing to ensure that players understand the behaviour and message of the game. Storytelling has the potential to provide the necessary connection. By backing up certain causalities and conditions with narratives, we can reduce the risk of misunderstandings.

4.3 Lessons from interdisciplinary work

The demands on the work of social researchers and game designers differ greatly, which is reflected in the respective working methods aimed at meeting these requirements.

In the social workers point of view, IPV is a structural problem, but it still happens to individuals. Each case differs in its conditions, process, intensity, its social environment and resources, and its impacts on the lives of the persons concerned. Multiple factors need to be considered to understand – and so to map – one single case, not to mention the construction of a map with every detail in the right context and interdependency. One case – and accordingly one individual life – cannot be measured or described comprehensively. In order to make joint but final decisions for a small part of the map as the basis for the digital game, the general game design approach first had to be agreed by the whole team. The domain experts needed to understand that strict computable mechanics needed to be set up, prototyped and tested. The team could then weigh the pros and cons of each potential play focus and its impact on the project objective: the primary prevention of IPV.

In previous social worker practice, live workshops offered the possibility to adapt a possible role play to the communication of the participants. In contrast, a digital game is usually played in the absence of the designers. The core of the game designers' work is to attract and maintain the players' attention in the game. To avoid loss of interest, games should be designed to be self-explanatory and intuitive through a simple core gameplay loop and clear feedback. Achieving this goal through game tuning is an iterative work process characterised by intermittent failures – a concept unfamiliar to social work researchers and therefore sometimes interpreted as a weakness.

For our serious game project, the requirements of both disciplines need to be considered. To be able to translate the highly complex structures of IPV into game mechanics, game designers had to simplify them. However, too much simplification could result in unintended messages or perpetuating stereotypes. Once the game is distributed, there is no possibility to interfere if there are misunderstandings or if the player behaves in an unexpected way. Therefore, these risks need to be identified in advance as best as possible. In our process so far, simplification had to be weighed against accuracy in several iterations throughout the early analysis and design phases.

These difficulties did not stem from the systems mapping approach but from the complexity of the topic, yet they became visible through this thorough exercise. Overall, the systems map wrapped the topic into a vivid and ostensive metaphor that facilitated discussions between the disciplines.

5. Conclusion

We described the systems mapping procedure used in our interdisciplinary team for acquisition and exchange of knowledge and for design. Research and design required different mapping approaches and had different goals. The research phase was about creating a system map that included as many aspects and interconnections as possible to show the big picture of a complex problem. The design phase was about breaking the big map down to the core aspects surrounding one main chosen leverage point.

Using the system mapping approach, we defined the core mechanic system of our serious game. The game is currently still in development and our approaches are yet to be tested and evaluated. We benefited from both the process and the results of systems mapping. It was a useful tool for research, design and collaboration.

A major limitation of systems mapping for complex social issues is that it is never entirely complete or accurate. Hence, identifying where to stop mapping and how to handle the incompleteness is already a contribution to design. Systems mapping does not provide solutions for difficult design problems, but it supports the process, making it more structured and substantial.

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Case Study on VR Empathy Game: Challenges with VR Games Development for Emotional Interactions with the VR Characters

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Abstract: Empathy development in young children (6 to 9 years old) sets a foundation for emotional regulation and social skills for children's futures. Researchers from the fields of virtual reality (VR) and game design highlight the potential of VR technologies as a great tool to promote empathy. However, there is little empirical and systematic knowledge on how to use VR technology to help promote empathy in young children. To address this gap, we developed a VR Empathy Game prototype to explore how VR experiences can inculcate empathy development in young children. To evaluate this prototype, we conducted a qualitative study with 15 children from 6 to 9 years old. We used an interpretive case study to provide an in-depth understanding of children's experiences with the VR Empathy Game. To guide participant selection, we used a purposeful sampling approach and intentionally included K-3 children with different empathy and social skills levels. This paper describes one case representing a challenge that children with a low level of empathy can experience while playing the VR Empathy Game. This case explains the game experience of a seven-year-old boy, Gabe. The case is entitled: "The VR Empathy Game Experience with a Focus on Exploring the Environment and Looking for Clues." Gabe confused intrinsic and extrinsic game goals and played the game focusing only on the VR environment. He perceived the game characters as an information source rather than building relationships with them unlike the children with a higher level of empathy. This case represents the group of four boys who participated in our study. In comparison with other participants, Gabe's case provided very little evidence of noticing the characters' emotions. Our findings suggest that game designers should provide additional scaffolding for children with little levels of empathy, including additional reflective questions and reminders to interact with the characters. We also suggest a follow-up study exploring how different storylines would help children's game experience.

Keywords: Virtual reality, empathy development, games for children, educational games, case study

1. Introduction

Designing games for empathy development is a new research area. There are no well-tested theoretical frameworks for such games. The most recent research in this area proposed a circular iterative empathy development model for analysing gamification strategies, which includes affective, cognitive, and behavioral aspects of empathy (López-Faican, 2021). However, there were no recommendations or further studies evaluating this model. In addition, this model did not specify the aspect of players' motivation and how it affects players' empathic experiences with the game.

Multiple researchers support using virtual reality (VR) as a promising tool for empathy development (Ang, 2008; Bayley, 2019). We found that children perceive and interact with VR characters as if they were interacting with real people (Muravevskaia, 2022). However, there is no clarity on how to design and scaffold such VR experiences to motivate young children to explore empathic interactions with VR characters.

To address these research gaps, we developed and qualitatively explored a VR Empathy Game prototype (Muravevskaia, 2017). This paper describes our lessons learned about designing a VR game for creating empathic interactions with the game characters. This paper describes potential challenges with a player's misinterpreting extrinsic and intrinsic goals of the game. To illustrate these challenges we used one case of a seven-year-old boy, Gabe, who was able to finish the game (extrinsic goal) without understanding the game characters' feelings (intrinsic goal). This paper provides game designers and researchers with insights on how to avoid such challenges.

2. Background

In this section, we discuss aspects of the educational game design, which relate to establishing the intrinsic and extrinsic motivation for the players. We then discuss the VR technologies related to the motivation of the players.

Extrinsic motivation. Ang (2008) distinguished two types of game goals: extrinsic and intrinsic. The extrinsic game goal is established in the game explicitly for the player through the game structure and narrative. Using

rewards for extrinsic motivation showed an increase in players' emotional involvement, however, it did not show any significant difference in learning outcomes (McKernan, 2015). In addition, Cohen (2001) states that children's games and play activities (badges, for example) based on extrinsic rewards have only a short-term effect on learning outcomes and strengthen a player's primary focus on rewards instead of the topic of study. Kohn (1991) suggests that using extrinsic rewards (e.g., badges or stars) as a method of motivation in games should be minimized because they decrease empathy overall. He suggests that for games designed with a focus on empathy development, an intrinsic motivation is preferred. Instead of using rewards, Rodrigo (2011) suggests using interactive characters and narrative, which can increase a player's emotional involvement as well. However, the relationship between the level of affective attachment and the player's motivation is not clear.

Intrinsic motivation. The intrinsic game goals are learning goals incorporated implicitly into the game (Ang, 2008). They might be organized as side objectives that help a player to achieve the main extrinsic goal. Tight interconnection between game narrative and educational content supports increasing intrinsic motivation, which serves as a basis for empathy development (Habgood, 2011; Aleven 2007). Habgood (2011) names a connection between narrative and education content, "intrinsic integration," which suggests keeping learning goals tightly aligned with the game's narrative and content. Intrinsic integration typically involves "concrete representations rather than abstract ones" (2011, p.175). However, the majority of these studies involve either middle or high school students (Rodrigo, 2011; Habgood, 2011; Ang, 2008), there is a research gap in regard to how the question of motivation should be approached in empathy development games for young children.

Researchers from the fields of virtual reality (VR) highlight the potential of VR technologies as a great tool to promote empathy (Bailenson, 2003; Bayley, 2019). The spatial and physical affordances of VR seem to have a great potential for creating more engaging and immersive experiences for children than 2D games (Bayley, 2019; Price, 2003). However, there is little knowledge on the ways in which VR technology can help motivate young children to have empathic interactions. For example, Bailenson (2004, p. 429) advocates that VR allows "changing the nature of social interaction" through the transformation of interpersonal communication for both virtual and real worlds. Such transformation relates to three different dimensions: representation of the VR characters, sensory capabilities of players, and situational context (Bailenson, 2004; Shriram, 2017). Shriram (2017) states that the proximity and behavior of the VR characters can affect the motivation and the mood of the player. In addition, we found that children express similar behavioral patterns with VR characters and real people (Muravevskaia, 2022). However, it is unclear how extrinsic and intrinsic goals of the game can be accomplished in order to provide a transfer from the learned material to players' real life. In this paper, we address this open question and bring more understanding of applying extrinsic and intrinsic goals in VR games for empathy development in young children.

3. VR Empathy Game Design

We designed the VR Empathy Game prototype as an initial step toward creating a framework for VR empathy games. The aim of this game was to create an empathic environment for a player by providing an opportunity to explore the emotions of different game characters and to learn to communicate with them by expressing prosocial actions.

We created our prototype in the research suggestions from the game design literature discussed in the Background section. We avoided using rewards for extrinsic motivation. Instead, we created the world of the game based on the communication between a player and the game characters. Each game character represented four basic emotions. The Goose character represented the emotion of fear, Baba Yaga - anger, the Older Sister - happiness, the Younger Sister - sadness. In order to keep the learning goals of the game (i.e., exploring the emotions of the game characters) tightly aligned with the game's narrative and the content, we chose the Russian traditional fairy tale "Magic Swan Geese". This fairy tale invited a player to go on an adventure of finding their VR brother. The way to find out where the VR brother is guided a player to interact with each of the characters. In our game, a player can collect information only through communication with the game characters. In addition, we created opportunities for reflections so a player can make cause-effect connections between feelings and the stories of different game characters.

Children were able to interact with the VR characters using the following features: (1) dialog, (2) memories, and (3) glasses. The Dialog feature provided an opportunity to ask the game characters questions. Children could view the memories of each character to understand how the character's past experiences shaped their

personalities and emotional behavior. By wearing each character's perspective glasses, the player can see the world from the character's perspective. Wearing glasses alters the world's colors, sounds, and other characters. In order to finish the game, players were implicitly prompted to express empathy action (i.e., hug the character) towards Baba Yaga in order to help her feel better and return the VR brother back to a player. Details of the VR Empathy Game prototype features are presented in our previous publications (Muravevskaia, 2017).

4. Methods

We designed a qualitative case study to investigate how children from 6 to 9 years old understood and interacted with the VR Empathy Game characters and its environments. Our study was approved by IRB #201600947, which required us to collect signed parent consent forms and verbal children's consent. We conducted individual 90-minute sessions for 15 participants. Each session included three 30-minute phases: (1) pre-surveys, (2) VR Empathy Game experience, and (3) post-surveys and post-interviews. Data collected included interviews, observations, and empathy scales surveys (Bryant, 1982; Reid, 2013). To analyze the data, we used thematic data analysis including inductive and deductive coding (Creswell, 2018). We used an interpretive case study methodology (Stake, 2006; Creswell, 2018) and constructed several cases to explore different types of how children understood and interacted with the VR Empathy Game. In this paper, we discuss one of the cases (see Findings).

We addressed trustworthiness criteria in the following ways. First, this study used investigator triangulation to enhance credibility (Polit & Beck 2006). Second, after finishing the coding process, we conducted peer inter-rater reliability (Creswell, 2018; Landis, 1977) on the post-interview data source. There were four researchers not associated with the project who participated in the inter-reliability process. The inter-rater reliability rate of agreement for codes was 77%. Third, we used thick descriptions, including the context of the study as well as direct quotes from participants (Nowel, 2017). Fourth, we triangulated the following data sources: interviews, observations, debriefing notes, and Empathy Scales. In addition, we used member checking with the school psychologist (Novell, 2017).

5. Findings

In this section, we present a case named, "The VR Empathy Game Experience with a Focus on Exploring the Environment and Looking for Clues," which represents 4 participants from our study. First, we introduce a participant who represents this case. Second, we provide a thick description of a gameplay experience. Third, we provide relevant excerpts from the postgame interview.

Gabe (a pseudonym used to protect the participant's identity) was a seven years old Caucasian boy, who had never had a full VR experience before and liked video games "a lot" (e.g., Pirates of the Caribbean, Lego). Considering Gabe's empathy level in real life, the school counselor described him as "having a hard time seeing from others' perspectives." Gabe's level of empathy, according to our Empathy Scales, was low (9 out of 14) which aligned well with the counselor's description of him. During the study process, Gabe was attentive to the researchers' words and followed the instructions. Gabe did not express many emotions. He seemed very calm, reserved, and answered our questions very directly and briefly. For Gabe, the VR Empathy Game was a "fun" experience, as he mentioned during the postgame interview. During the gameplay experience, he often exclaimed "cool" while seeing new objects or features in the VR environment. Navigation and operation with the game features were easy for Gabe. There were no usability challenges observed.

5.1 Study Experience

The study took place in a local elementary school in Florida, USA. The school counselor escorted Gabe to a room dedicated for the study. Then, the counselor left the room. Katrina, the researcher, guided the process while two other researchers helped with observations and taking notes. First, Gabe completed the pre-surveys. Then, Katrina explained how to use VR controllers to interact with characters and move between environments. Katrina also let Gabe know that he may stop the game any time if he needed. Then, she helped him put on the equipment and he started the game.

The VR game used for the study included different environments with different characters to interact with. After the introduction of the game was done, Gabe entered the Goose's environment, he immediately noticed the Goose. However, before interacting with the Goose, Gabe turned around and set off to explore the Goose's environment. After making a circle around the space, Gabe approached the Goose and asked him a question.

Gabe did not look at the Goose while listening to his response but instead looked around the environment. Then Gabe selected the Goose's memories. While watching the Goose's memories, Gabe periodically got distracted and looked around the VR environment and played with his VR hands. Gabe was less involved in the characters' memories and periodically looked around. Then, he went to Baba Yaga's environment.

First, Gabe walked around exploring the environment. At the moment when Baba Yaga appeared, Gabe took a step back from her in a way that suggests he was readjusting his position in order to see her better or to create a more comfortable social distance. Gabe asked Baba Yaga a question. Without waiting till the end of Baba Yaga's answer to his question, Gabe put on Baba Yaga's glasses and looked around. Then he left Baba Yaga and went to the Older Sister.

When Gabe arrived at the Older Sister's environment he walked around and explored. After Gabe saw the Older Sister, Gabe turned around and went to the plate with the environment again. The Older Sister, designed to engage with the players and not necessarily to respond to Gabe's unexpected behavior, coincidentally asked, "What are you looking for, child?" After hearing these words from the Older Sister, Gabe came to the Older Sister and asked her a question. He listened to her answer. Then, Gabe left The Older Sister's environment and went to the Younger Sister without checking Older Sister's glasses and memories.

In contrast to the previous environments, after entering the Younger Sister environment Gabe went directly to the Younger Sister. Noticing a new feature available (i.e., hug), he hugged her. However, he did not recall the act of hugging her during the postgame interview. He immediately switched to observing the environment and did not express interest in interacting with the Younger sister. Then, Gabe came back to the Younger Sister and asked her a question. After listening to the Younger Sister's answer, Gabe left the Younger Sister's environment to the Forest. After two minutes of playing with a stick, Gabe returned to the Younger Sister. Gabe watched the Younger Sister's memories, and periodically glanced at the environment and back to the screen playing the memories.

Afterward, Gabe returned to Baba Yaga's environment. Noticing the Hug feature, Gabe hugged Baba Yaga. In response to Gabe, Baba Yaga said that it is so kind of him, but she still is not returning the brother. Gabe walked around and then came to Baba Yaga and hugged her again. Then, Baba Yaga got kinder and said that she is sorry for being angry, and she returned Gabe's brother to him. The game was over. It took Gabe exactly 30 minutes to finish the game. Even though it appeared that he was interacting mostly with the environment, moving back and forth between environments, and only passively interacting with the dialog and empathy features, he was able to finish the game in time without help from the researchers.

5.2 Interview Excerpts

During the postgame interview, Gabe, referring to the game, said that "it was a fun experience." When we asked Gabe whom he imagined himself in the game to be, Gabe said: "I was myself." This suggests that he did not imagine himself being any of the game characters from the game story. Even though he identified himself as a child of the VR parents when asked about the game's goal, he did not say "my" brother or "my" parents as some of the other children did. This might suggest less social engagement with the game characters. When asked about the goal of the game, Gabe said that the goal was "to get brother" in order "not to get in trouble with [VR] parents," which was the extrinsic game goal. Gabe said that characters' words and features were "the clues" for finishing the game, and he considered them the sources of the information. Gabe also figured out that "giving a hug to Baba Yaga helped to get the brother back" even though he did it "only to get the brother back."

When Katrina asked Gabe about what the Glasses showed, Gabe simply answered that Glasses showed "things that I may have not seen or heard without the glasses." Gabe did not mention the characters' emotions or how they felt. When asked about the Memories feature, Gabe said that the memories represented "the past that they [characters] remembered." Gabe clarified that "at the very end they [memories] all had different parts." It seemed that Gabe was able to see the connection between all the memory pieces presented by different characters, however, Gabe was not able to make connections between Baba Yaga's past and her current emotions.

6. Discussion

In this section, we discuss our findings and describe the role the VR Empathy Game played in a participant's experience. Also, we outline implications and make suggestions for future work. Our findings provide evidence

of the VR Empathy Game serving as an opportunity to explore a VR environment. However, we observed that Gabe was not interested in interacting with the characters. Gabe was following the arch of the game narrative, which represented an extrinsic goal. However, he did not connect this information with the characters' feelings, which was our intrinsic goal. Gabe perceived the characters and the information they shared as game clues. We suggest that Gabe's behavior was caused by the challenges with empathy. In this subsection, we discuss these findings in the following order: (1) Immersion in the Gameplay Process, (2) Challenges with Focus on Characters and with Engagement into the Storyline, (3) Lack of Empathy Evidence, (4) Potential VR Empathy Game Experience Challenges.

6.1 Immersion in the gameplay process

Brown (2004) suggested that attention to the game task is an important indicator of immersion referring to immersion. Gabe remembered all the pieces of memories from each character and was able to make connections between them. This suggests that even if his behavior looked distracted and seemingly haphazard movement from one environment to another, Gabe was attentive to the information he was collecting from the game. Also, Gabe expressed attention to the game environment objects and experimented with playing with sticks and cones in different ways (e.g., throwing, exploring how they go through another). While Gabe's case did not provide visual evidence of his attentiveness to the communication with the characters as he was noticeably distracted by the environment while watching characters' memories or listening to their words.

6.2 Challenges with a focus on characters and with engagement in the storyline

Gabe did not express much interest in interacting with the characters. For example, upon entering an environment, he did not rush to ring the bell to interact with the characters. In each environment except for the Younger Sister, Gabe took some time to explore the objects the environment had to offer (e.g., sticks and pinecones) before calling the character. Once Gabe met the characters, they did not draw his attention for more than several seconds. For example, right after Gabe came to the Goose's environment and noticed the Goose, he turned around and went to look around the environment without rushing to approach the goose just yet. Only after making the circle around the space, Gabe approached the Goose and picked one of the Dialog questions to ask the Goose. The same happened in the Older Sister's environment. While listening to the characters' initiated Dialog feature, he did not look at them but rather looked around the environment. For example, Gabe did not look at the Goose while listening to his response but looked around the environment instead. Sometimes Gabe interrupted the characters speaking by using another game feature. For example, without waiting till the end of Baba Yaga's answer to his question, Gabe put on Baba Yaga's glasses. This suggests Gabe was not interested in interacting with the characters and getting to know them.

6.3 Lack of empathy evidence

In order to understand why the character feels a specific way, a child needs to recognize that character feels an emotion (i.e., affective empathy) and to understand the reason why this character feels the way that they do (i.e., cognitive empathy) (Obuchova, 2006). In our research, we considered emotional recognition as evidence of affective empathy (Jardine, 2015; Decety & Svetlova, 2012). We were looking for evidence of Gabe understanding how characters felt. Of all the characters, Gabe correctly named only the emotion of the Older Sister, which was "happy." For the other characters, Gabe was a bit confused in his naming of their emotions. He called the Younger Sister, who was sad and crying, "mad." Goose's emotion, which was fear, was identified by Gabe as "mad" because "he [Goose] had to do things for Baba Yaga." Interestingly, Gabe constructed the cause and effect of the emotions of the characters based on their past experience. However, the cause and effect were based on his subjective explanation rather than what was happening in the game story. During the postgame interview, Gabe struggled with identifying the characters' emotions. Gabe was using the words "I guess" every time we asked him to describe the emotions of the characters. This suggests that he was not sure of his answers. This suggests evidence that Gabe was challenged with emotional recognition, which was a construct of affective empathy in our research.

Cognitive empathy is based on understanding why the character feels a specific way (Obuchova, 2006). When we asked Gabe about the reasons why characters feel the way they do, Gabe explained why characters felt the way they did based on his subjective assumptions rather than the real stories from the game memories. Gabe connected all the game pieces. However, Gabe's ability to connect the parts of the game did not hint Gabe to connect it to the characters' emotions. Moreover, we have noticed that while answering questions about the character's emotions, Gabe felt tired and distracted. We suggest that he was not interested in talking about emotions. We got the impression that Gabe did not even understand why we asked him questions about

emotions and how it connects to the game. Therefore, we suggest that Gabe's case did not provide evidence of cognitive empathy.

6.4 Potential VR Empathy Game experience challenges related to extrinsic and intrinsic goals

The findings from our case study contribute to the Game Design field by addressing Ang's (2008) open question about how to use intrinsic and extrinsic goals in educational game design. Ang (2008) distinguished two types of game goals: extrinsic and intrinsic. The extrinsic game goal is established in the game explicitly for the player. While the extrinsic goals are externally imposed by the game structure and narrative, the intrinsic game goals are learning goals incorporated implicitly into the game. They might be organized as side objectives that help a player to achieve the main extrinsic goal. In our VR Empathy Game, the extrinsic goal was to complete the game by saving the VR brother. Our intrinsic goal was to identify the emotions of the characters (affective empathy), to build the cause and effect understanding, of why characters feel that way (cognitive empathy), and to act prosocially toward Baba Yaga to make her feel better. Ang (2008) suggested no empirical clarification about which goals might be more beneficial for empathy games in game design research. We suggest that an intrinsic goal is more important for educational empathy games and they are built on the extrinsic goals of the games. It is important to set extrinsic goals so that these goals guide the child's understanding of the intrinsic goal instead of mechanical actions to complete the game.

In our VR Empathy Game, players need to leverage both the intrinsic and extrinsic goals to save the VR brother. We designed the VR Empathy Game so that without empathy towards the characters (intrinsic goal), players cannot find a brother (extrinsic goal). However, we observed children like Gabe performing the game empathy actions towards finishing the game without empathizing with the characters and even without understanding their emotions, but rather as a part of the game mechanics. Therefore, players like Gabe achieved the extrinsic but not the intrinsic goal, which was the ultimate game's goal.

6.5 Implications

We found the narrator's reminders helpful to keep children focused on the characters. After hearing the words "What are you looking for here, child?" from the Older Sister, Gabe came to the Older Sister and asked her a question. This suggests that game reminders to return to the storyline and game characters helped Gabe remember the characters and return to interacting with the game character. For game designers, this is a design suggestion to draw the attention of children to the game characters. This can be helpful for students who are not attentive or easily distracted. It also can be helpful for children who prefer exploration of the VR environment to interactions with the game characters.

6.6 Future Research

We suggest follow-up research to explore how to set and scaffold extrinsic game goals for children like Gabe so that achieving them would help such children to understand and achieve an intrinsic goal. Following Chapman (2007), who found that boys tend to get more interested in the information while girls are interested in narrative and characters' feelings, we suggest paying attention to the gender differences in VR Empathy Game experiences to conduct further research. It could potentially suggest using different narratives for children of different genders and with different levels of empathy.

7. Conclusion

This paper described a case representing a challenge that children with a low level of empathy can experience while playing the VR Empathy Game: "The VR Empathy Game Experience with a Focus on Exploring the Environment and Looking for Clues." This case illustrated a potential confusion by children between intrinsic and extrinsic game goals. It might cause perceiving the game characters as an information source rather than building relationships with them, as children with a higher level of empathy did. This case represented very little evidence of noticing the characters' emotions. Our findings suggest that game designers should provide additional scaffolding for children with little levels of empathy, including additional reflective questions and reminders to interact with the characters. We also suggest a follow-up study exploring how different storylines would help children's game experience.

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Games for Teaching and Learning History: a Systematic Literature Review

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Abstract: This work shows a systematic literature review carried out within Scopus database to identify educational projects where games have been used to teach geography and history in secondary education. Following most of PRISMA methodology procedures, while adapting some of its protocols, we identified 255 works. After the first data cleaning, we applied our inclusion and exclusion criteria to end up with 125 relevant results which were refined in later stages. Within our final sample, we applied descriptive statistics to confirm that most projects appear in conference proceedings and that they use mainly educational games created *ad hoc* instead of commercial games. Many times, these projects have not been implemented and even in these cases, their educational impact is rarely measured rigorously.

Keywords: video games, history, geography, systematic literature review, COTS

1. Introduction

Video games are a form of convergent media that involve narrative elements and ludic components. Despite the attempts made by several authors to define what a video game is (Juul, 2010; Salen and Zimmerman, 2004), in this work, we understand video games (and also physical games) as artistic products, created with a ludic intention, which provide an artificial system accepted by the players who interact with it in a new complex experience that depends mainly on the emotional dimension (Oceja, 2020).

Furthermore, video games, like other cultural artifacts, represent a diverse media that can take the form of casual games, Commercial Off-the-Shelf Games (COTS), or artistic pieces exploring creative possibilities. This diversity in video games is also becoming diversity in who plays video games. In the United States, 55% of players are men and 45% are women (Entertainment Software Association, 2021) with similar data in Europe, where 53% of players are men and 47% of women. The average age of players is more than 30 years old and the ways and devices where they play (57% mobile, 46% home consoles, and 42% PC) also highlight this diversity.

The increased popularity of video games has been accompanied by some criticism in the mass media which many times has approached games through stereotypes and simplifications. Among them, we find the characterization of players as a homogeneous community, the bias shown when representing events such as esports as competitions destined only to teenage, desensitized boys, or the representation of games only through triple-A and blockbuster games. Furthermore, one of the most common negative stereotypes is the idea of games as problematic media responsible for causing addictions and violence.

Admitting that some best-selling games could confirm partially those clichés, it is important to note that video games offer great educational possibilities. For instance, a meta-analysis carried out by Sitzmann and Ely (2011) with more than 55 studies showed that simulation games could improve self-efficacy by 20%, declarative knowledge by 11%, procedural knowledge by 14%, retention by 9%, and transfer by 5%. Besides their impact on the learning process, other authors mention benefits associated with spatial abilities (Green and Bavelier, 2003) or the ability to solve problems (Ko, 2002). Moreover, video games can also bring benefits in the acquisition of educational content that is part of the official curriculum. This has been studied extensively for several subjects such as math (Ottar and Hanghøjh, 2020), language arts and literature (Beavis, 2014) and foreign languages (Rudis & Poštić, 2017).

Nevertheless, the educational possibilities of games for teaching Geography or History, has not been explored deeply and it is not easy to find scientific works documenting in detail good educational projects. In fact, there is no information about what academic production (academic journals, conference proceedings, etc.) has tried more consistently to do that. Also, within this scientific production, it is not clear what kind of games do these

projects advocate for, what methodological approaches are being used, and to what extent their educational impact has been measured.

Historically, methodological approaches have depended on the prevailing educational theory at each time. For instance, behaviorism has looked at games as an opportunity to promote responses based on rewards. On the contrary, uses from a cognitive perspective underlined the limitations of behaviorism while focusing on the cognitive aspects involved in the process of playing (Malone and Lepper, 1987), which brought richer experiences and the use of more complex games. In turn, constructivist approaches, which remain scarce, highlight the importance of players interacting with the digital environment and with other players to build knowledge as it would happen with games like *Minecraft*. Along the same lines, we find contributions from constructionism, a closely related sub-theory that focuses on the benefits of students/learners designing their own games (Papert, 1993). Finally, we must mention the so-called sociocultural approaches. In this framework the explicit educational content of the game is not the most important element for learning. On the contrary, it advocates for the use of commercial games (COTS), with no explicit educational content, emphasizing the importance of what happens around the game experience: the conversations, the places where they are played, the critical role of the teacher, etc. While acknowledging good practices through educational games such as DragonBox (Gibbs, 2020) or the Global Conflict series (Moreno Cantano, 2020), we agree with Gee (2014) when he highlights the benefits of using COTS dialogically mediated by teachers. However, Hanghøj (2018) has highlighted the historical lack of research focusing on these games in comparison with educational games. Hanghøj also mentions that the most important factor for success (both using educational games and COTS) is the way they are deployed through pre-game and post-game activities. One example could be the educational project *Playing Emotions* (Oceja, 2019) which tries to promote emotional competence through indie games such as *Braid* or *Gris* with activities before, during, and after the game.

However, as we anticipated, there is a lack of knowledge on what kind of academic works have documented these educational projects. We are especially concerned with this issue as we agree with Miller (1999) when he points out the historical distance between real educational practices and academic production.
Thus, we theorize that the most important academic format (academic journals) might not gather all this evidence as well as others that have been traditionally marginalized.
Following this rationale, in this paper we try to answer the following research questions (RQ):

- RQ1. What kind of academic works (conference proceedings, journal articles, etc.) document educational projects aiming to teach Geography and History through games?
- RQ2: What kind of games (educational games, COTS, etc.) are being used in these educational projects?
- RQ3: What are the main methodological approaches (using existing COTS, using educational games, making students design their own games, etc.) are used when working with games?
- RQ4: To what extent is the impact of projects based on COTS measured?

To do all that, carrying a systematic literature review seems to be the most adequate methodology.

2. Methods

Systematic literature reviews are becoming critical when facing any rigorous scientific work. Mapping an academic field to know the most important contributions is important to build new useful knowledge. Jesson et al. (2011) distinguish between traditional and systematic reviews. The first ones have positive features such as the flexibility to explore ideas and, when needed, give authors the chance to express their subjectivity. However, they have problems like including bias, personal opinions, or relying too much on the skills of the researchers.

On the other hand, systematic reviews propose a more rigorous approach based on a specific methodology, with more transparency, and with a degree of replicability that allows researchers to imitate the procedures of a particular work. Jesson et al. (2011) mention the following phases: scope and map, plan and protocol, document, inclusion and exclusion criteria, search and screen, quality appraisal, data extraction, and synthesis.

In the last years, we have seen different initiatives to consolidate these approaches. Probably, the most important ones have been the Quality of Reporting of Meta-analyses (QUORUM) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al, 2009). This model provides a guide to improve the quality of the reviews, providing researchers with a clear and common procedure. Only a few adjustments have been made in this work such as (1) not removing duplicates as we used only one metadata

base (Scopus) and (2) working with two sets of data depending on the RQ we were answering (78 for RQ1, 2 and 3 and 11 for RQ4).

2.1 Search

This review is based on Scopus, an Elsevier's database. Several authors have mentioned that Scopus can outscore other services such as Web of Science (WOS) being more inclusive and comprising more sources (Bosman et al, 2006). Specifically, Scopus covers 36377 sources from 11678 publishers, with 34346 academic journals with peer review.

In this proposal, we have focused on projects using games to teach/learn geography and/or history in secondary education. Both disciplines have been understood as a single unity of analysis following historiographical criteria, as some countries such as Spain or France have tended historically to unite both as a single subject. We ran the search in March 2022 and after several tries, we decided to use a wide query to include as many projects as possible. The boolean operators used were:

(TITLE-ABS-KEY (*game*) AND TITLE-ABS-KEY (history) OR TITLE-ABS-KEY (geography) OR TITLE-ABS-KEY ("social studies")) AND (TITLE-ABS-KEY (secondary) OR TITLE-ABS-KEY ("high school")) AND (TITLE-ABS-KEY (teach*) OR TITLE-ABS-KEY (learn*) OR TITLE-ABS-KEY (student*))

After this first search, we ended up with a significant number of works (n = 255). After applying the first inclusion criteria, we ended up with a more manageable set (n = 125). Those criteria were:

- Works documenting game-based educational projects
- Projects focusing on teaching/learning history
- Projects focusing on secondary education

We then applied some exclusion criteria to end up with the final works assessed for eligibility. Those were:

- Book chapters based on theoretical contributions
- Model's design
- Books based on theoretical contributions
- Not focusing on secondary education
- Not focusing on Geography/History
- Not focusing on games
- Not implemented
- Not in English
- Teachers' perceptions on GBL
- Critical reviews
- Literature reviews

We used the resulting sample (n = 78) to answer the first, second, and third research questions. Those articles are shown in Table 1.

Finally, as the last research question focused only on COTS, we had to add extra inclusion criteria: Projects including the use of COTS for learning/teaching Geography and/or History in Secondary Education (n = 11)

Figure 1 shows the whole procedure with all the inclusion and exclusion criteria.

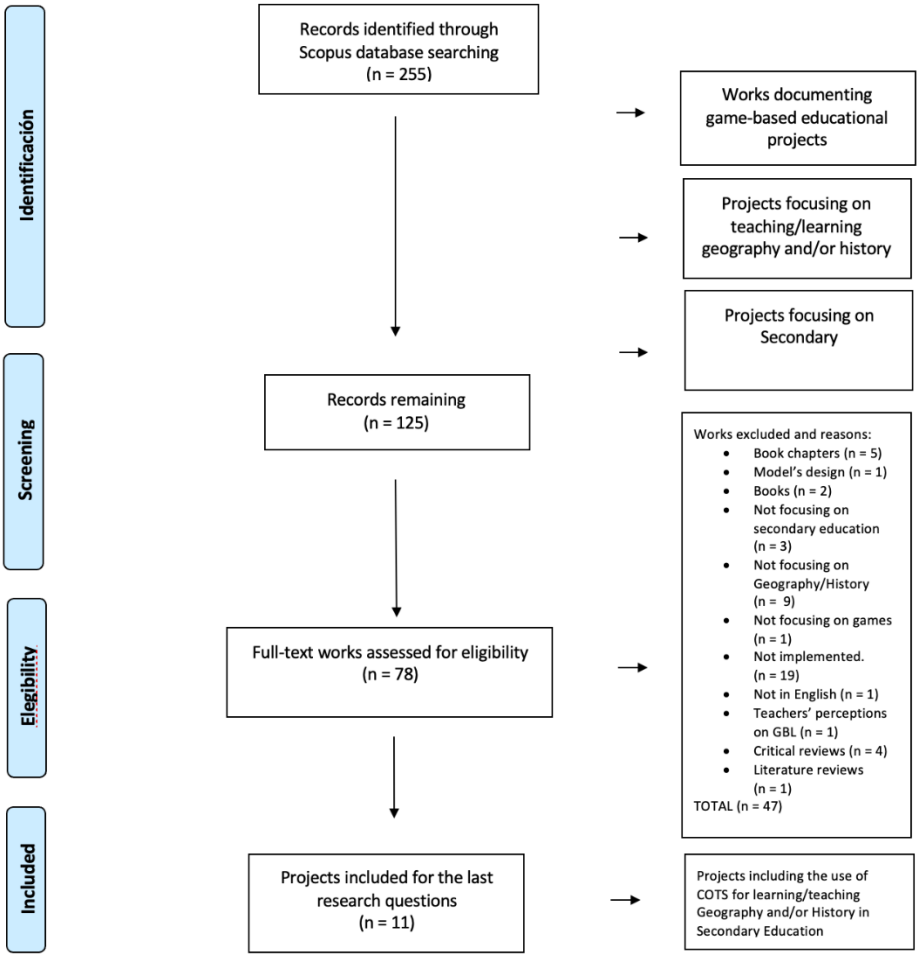


Figure 1: Procedure followed in the review

3. Results

The following table shows the 78 games used for answering questions 1, 2 and 3.

Table 1: Works documenting the use of games for teaching Georgrafy and/or History

Authors	**Title**
Admiraal, W. Huizenga, J. Akkerman, S. & Dam, G.T.	The concept of flow in collaborative game-based learning
Akkerman, S. Admiraal, W. & Huizenga, J.	Storification in History education: A mobile game in and about medieval Amsterdam
Bachen, C.M., Hernández-Ramos, P.F., Raphael, C. & Waldron, A.	Civic Play and Civic Gaps: Can Life Simulation Games Advance Educational Equity?
Baker, M. Bernard, F.-X. & Dumez-Féroc, I.	Integrating computer-supported collaborative learning into the classroom: The anatomy of a failure
Barkand, J. & Kush, J.	GEARS a 3D virtual learning environment used in online secondary schools
Bedi, K. Hrustek, N.Z. & Ćorić, A.	Teaching vs. 3D gaming in secondary school
Bikar, S.S. Sharif, S. Rathakrishnan, B. & Talin, R.	Students' Perceptions about the Use of Minimalist Robotic Games in Geography Education
Bralia, C. & Catenazzi, N.	Two-fold learning: Learning by developing and learning by playing
Buchtová, M. Šisler, V. & Brom, C.	Educational games and simulations at school: Experimental comparison with classic teaching methods and requirements of successful implementation into school environment and curricula
Charsky, D. & Ressler, W.	"Games are made for fun": Lessons on the effects of concept maps in the classroom use of computer games
Chee, Y.S. Mehrotra, S. & Liu, Q.	Effective game based citizenship education in the age of new media

Authors	Title
Chou, Y.-S. Hou, H.-T., Chang, K.-E. & Su, C.-L.	Designing cognitive-based game mechanisms for mobile educational games to promote cognitive thinking: an analysis of flow state and game-based learning behavioral patterns
Chou, Y.-S., Hou, H.-T., Su, C.-L. & Chang, K.-E.	Designing and evaluating a mobile educational game “Void Broken 2.0” for history instruction
Craft, J.	Rebuilding an empire with minecraft: Bringing the classics into the digital space
Deslis, D. Kosmidis, C.-V. & Tenta, E.	Using a non-educational mobile game for learning in biology, geography and mathematics: Pokémon go as a case study
Di Blas, N. & Poggi, C.	Investigating entertainment and learning in a multi-user 3D virtual environment
Di Blas, N. Paolini, P. & Poggi, C.	Factors influencing chat-based cultural discussions for learning history in a 3D virtual world
Díaz, J. Queiruga, C. Tzancoff, C.B. Fava, L. & Harari, V.	Educational robotics and videogames in the classroom
Dietz, M.	The effects of role-play from a history didactical perspective
Drosos, V. Alexakos, C. Alexandri, A. & Tsolis, D.	Evaluating 3D serious games on cultural education
Earp, J. Catalano, C.E. & Mortara, M.	Investigating the deployment of serious games in secondary education: A pilot study inspired by design-based research
Egunjobi, A.O.	Efficacy of three computer-assisted instructional modes on students' academic performance in secondary school practical geography in Nigeria
Ewen, T. & Seibert, J.	Learning about water resource sharing through game play
Fialova, D.D.	Challenges for student's skills and attitudes within social studies conventional simulation games
Fullerton, T. Malamed, L.M. Sharkas, N. & Vigil, J.	Designing history: The path to participation nation
Galí, C. Remolar, I. & Rebollo, C.	Visiting Ancient Rome with a serious game
Gaydos, M.	Developing a geography game for Singapore classrooms
Gwee, S. & Tan, E.M.	Developing a sense of identity as a governor within a mobile learning community
Gwee, S. Chee, Y.-S. & Tan, E.-M.	Assessment of student outcomes of mobile game-based learning
Hadi, A.A.R. Wan Daud, W.M.F. & Ibrahim, N.H.	The development of history educational game as a revision tool for Malaysia school education
Henriet, J.-M.	On using simulation games in secondary schools: the example of ACIERIX, France).
Hofmann, J.	Can playing an “unfair game” promote ethical decision-making? The use of the “trading game” in secondary-school geography lessons
Holden, J.I., Kupperman, J. Dorfman, A. Saunders, T. Pratt, A. & MacKay, P.	Gameful learning as a way of being
Huizenga, J. Admiraal, W. Akkerman, S. & Ten Dam, G.	Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game: Original Academic journal
Huizenga, J. Admiraal, W. Akkerman, S. & Ten Dam, G.	Learning history by playing a mobile city game
Huizenga, J. Admiraal, W. Akkerman, S. &Ten Dam, G.	Cognitive and affective effects of learning history by playing a mobile game
Hwang, G.-J. Chien, S.-Y. & Li, W.-S.	A multidimensional repertory grid as a graphic organizer for implementing digital games to promote students’ learning performances and behaviors
Jenson, J. Black, K.R. & De Castell, S.	Designing, tinkering and making: Implementing digital games in classroom contexts
Jong, M.S.Y.	Does online game-based learning work in formal education at school? A case study of VISOLE
Karademir, N.	Secondary School Students' Attitudes toward the Geography Course
Katalinić, E.	Travelling across Euroland [Potovanje po Evrolandiji]
Kesuma, A.T. Harun, Putranta, H. Mailool, J. & Adi Kistoro, H.C.	The effects of MANSA historical board game toward the students’ creativity and learning outcomes on historical subjects
KoÅ‚odziejczyk, A.M. Rzepa, A. CieÅ›lak, B. & Harasymczuk, M.	Educational analog missions in Lunares habitat in Poland
Kusuma, G.P. Putera Suryapranata, L.K., Wigati, E.K. & Utomo, Y.	Enhancing Historical Learning Using Role-Playing Game on Mobile Platform

Authors	Title
Lim, K.Y.T. & Wang, J.Y.Z.	Collaborative handheld gaming in education [Jeux collaboratifs sur portables en éducation] [Gemeinschafliches Spielen auf Handhelds oder Handys als Unterricht]
Lin, K.-C. & Wei, Y.C.	Online Interactive Game-based Learning in high school history education: Impact on educational effectiveness and student motivation
Lin, K.-C., Wei, Y.C., &Hung, J.C.	The effects of online interactive games on high school students' achievement and motivation in history learning
Lin, Y.-H.	Pokémon: Game play as multi-subject learning experience
Mollica, A.	Games and Language Activities in the Italian High School Classroom
Mystakidi, S. Lambropoulos, N. Fardoun, H.M. & Alghazzawi, D.M.	Playful blended digital storytelling in 3D Immersive eLearning Environments: A cost effective early literacy motivation method
Nor Azan, M.Z. & Wong, S.Y.	Game based learning model for history courseware: A preliminary analysis
Nugroho, S.M.S. Rahman, M.D.A. Hariadi, M. & Arief, M.	Development of Educational Game for Indonesian History Lesson Focusing on Indonesia Pre-Literacy Relics 'Prehistoria' for Grade X High School Student
Öztürk, Ç. & Korkmaz, Ö.	The effect of gamification activities on students' academic achievements in social studies course, attitudes towards the course and cooperative learning skills
Pease, M. Pérez-Lapeña, B. & Lant, C.	Energy and water resource simulations for U.S. geography undergraduates
Pee, N.C. Blanchfield, P. & Higgins, C.	Teaching climate change in Year 8!
Pitura, J. & Terlecka-Pacut, E.	Action research on the application of technology assisted urban gaming in language education in a Polish upper-secondary school
Putra, E. Tantular, B.A. & Ruhimat, M.	The Effect of Simcity as Instructional Media in Geography Learning on Learners' Spatial Intelligence
Remolar, I. Rebollo, C. & Fernández-Moyano, J.A.	Learning history using virtual and augmented reality
Repantis, V. & Delidaki, S.	Engaging students in developing a stereoscopic 3D educational history game
Rüth, M. & Kaspar, K	Commercial Video Games in School Teaching: Two Mixed Methods Case Studies on Students' Reflection Processes
Sánchez, M.J.J.-M.	The use of video games for the teaching of ancient history in secondary education: An educational investigation [El uso de los videojuegos para la enseñanza de la historia antigua en educación secundaria: Una investigación educativa]
Schnürer, R. Dind, C., Schalcher, S. Tschudi, P. & Hurni, L.	Augmenting printed school atlases with thematic 3D maps
Selmbacherova, T. Sisler, V. & Brom, C.	The impact of visual realism on the authenticity of educational simulation: A comparative study
Šisler, V. Brom, C., Cuhra, J. Činátl, K. & Gemrot, J.	Stories from the History of Czechoslovakia, A serious game for teaching history of the Czech lands in the 20th century - Notes on design concepts and design process
Šisler, V. Selmbacherová, T.,Pinkas, J. & Brom, C.	Teaching contemporary history to high school students: The augmented learning environment of Czechoslovakia
So, H.-J. Gaydos, M. Seo, M. Jung, Y. & Lee, H.	Learning with minecraft and kodu: Examining complex problem-solving strategies
Sorensen, E.K. Poulsen, M.,Houmann, R. & Mortensen, P.-E.	Interactive whiteboards and computer games at high school level: Digital resources for enhancing teaching and learning
Teo, C.T. & Chee, Y.S.	The effect of gaming on secondary students' thinking, beliefs, creativity and skills: A preliminary study in social studies lessons
Wang, D.	Gamified learning through unity 3D in visualizing environments
Wang, S.-M. Hsu, H.-Y. Keng, S.-H. & Hou, H.-T.	The development and preliminary evaluation of a street view-based educational game - “guarding Ka-lah-a©”
Watson, W.R. Mong, C.J & Harris, C.A.	A case study of the in-class use of a video game for teaching high school history
Weitze, C.L.	Reflective, creative and computational thinking strategies used when students learn through making games
Wijers, M. Jonker, V. & Kerstens, K.	MobileMath: The phone, the game and the math
Wilms, D.C. & Steinbrink, J.E.	Escalation: A simulation of contemporary GEO-politics
Yu, Z. Yu, W.H. Fan, X. & Wang, X.	An exploration of computer game-based instruction in the "world history" class in secondary education: A comparative study in China

Authors	Title
Yue, W.S. & Ying, C.Y.	The Evaluation Study of Gamification Approach in Malaysian History Learning via Mobile Game Application
Zhu, K. & Huen, M.H.J.	Teaching and learning of Chinese history in minecraft: A pilot case-study in Hong Kong secondary schools
Zin, N.A.M. & Yue, W.S.	Design and evaluation of history Digital Game Based Learning (DGBL) software

Regarding the first research question, as seen in figure 1, we explored how many of the projects appeared in academic journals and how many in conference papers.

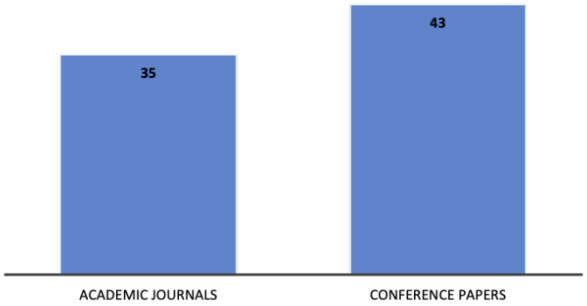


Figure 2: Number of projects appearing in academic journals and those appearing in conference papers

Out of 78 works, conference papers (n = 43) outscored those published as articles in academic journals (n = 35).

Regarding the second and third research questions, the following graphic shows what kind of approaches were used when bringing games to the classroom.

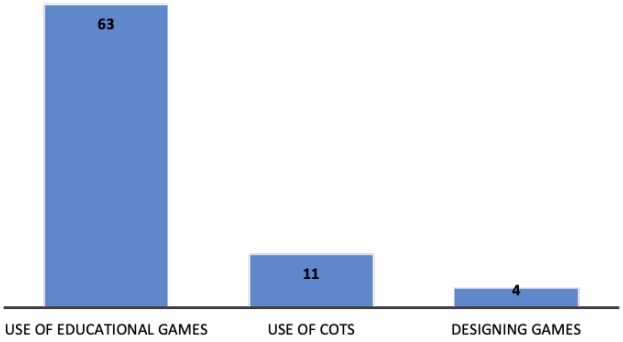


Figure 3: Number of projects that use educational games, COTS, or the methodology of students designing their own games.

Clearly, most projects use educational games to work on content knowledge. Most of those games have been designed *ad hoc* for these studies. It was surprising the shortage of teachers using COTS, as in all 78 works, only a few projects (n = 11) used commercial games. Those games were Sim City, Kodu, Minecraft (in three projects), Age of Empires, Pokemon Go, Civilization, Pokemon, Spore and Valiant Hearts, Dominations, and Second Life.

It also called our attention that other experiences, such as students designing their own games, were particularly scarce (n = 4).

Finally, to answer the fourth research question Table 2 shows all the projects using COTS, indicating if the educational impact was measured and, in that case, what variables were assessed, under what methodology, and with what results.

Table 2: Works documenting the use of COTS including if there is any measurement in the project and, in this case, the main variables, methodology, and results

Title	**COTS**	**Meas**	**Variables**	**Methodology**	**Results**
The Effect of Simcity as Instructional Media in Geography Learning on Learners' Spatial Intelligence	Sim City	Yes	Spatial intelligence	Quantitative. Quasi-experimental. Inferential statistics (T-test)	Improves spatial intelligence
Learning with minecraft and kodu: Examining complex problem-solving strategies	Minecraft And Kodu	Yes	Ability to solve complex, ill-defined problems	Qualitative. Open-ended problems that they discussed and solved as groups. Discourse data was transcribed and analyzed.	Minecraft and Kodu, coupled with a PBL curriculum, can help students in tackling complex, ill-defined problems by improving their use of models and planning practices
Teaching and learning of Chinese history in minecraft: A pilot case-study in Hong Kong secondary schools	Minecraft (2)	Yes	Motivation, students, and teachers' perception about the experience	Mixed methods. Questionnaires for motivation (ANOVA), feedback from teachers and students for perception	Motivation increased significantly. Most students enjoyed the experience. Teachers appreciated the experience even though more history knowledge within the game experience is demanded
Rebuilding an empire with minecraft: Bringing the classics into the digital space	MInecraft (3)	Yes	Content knowledge	Quantitative. Pre-and post-written assessments (not advanced statistics)	Improvement in the understanding of Roman architecture
An exploration of computer game-based instruction in the "world history" class in secondary education: A comparative study in China	Age of Empires	Yes	Content knowledge and motivation	Mixed methods Quantitative (pretest/posttest experiment) -content knowledge- and qualitative (feedback questionnaire) -motivation-	(1) Greater learning achievement (2) (3) there were no significant differences in learning achievement between boys and girls; although (4) boys were significantly more motivated
Using a non-educational mobile game for learning in biology, geography and mathematics: Pokémon go as a case study	Pokemon Go	Yes	Attitudes towards the subject	Qualitative. Observation, field notes, and interviews	Effective integration of mobile technologies can enhance learning and students' attitude
"Games are made	Civilizati	Yes	Motivation	Quantitative.	Motivation towards the

Title	COTS	Meas	Variables	Methodology	Results
for fun": Lessons on the effects of concept maps in the classroom use of computer games	on		towards the instructional material (Instructional Materials Motivation Scale (IMMS)	ANOVAs and other advance inferential statistics	activity increases when using games vs. traditional class. Using conceptual maps when using games shows lower motivation
Pokémon: Game play as multi-subject learning experience	Pokemon	NO	N/A	N/A	N/A
Commercial Video Games in School Teaching: Two Mixed Methods Case Studies on Students' Reflection Processes	Spore and Valiant Hearts	Yes	Qualitative: Perception on the experience Quantitative: Topic knowledge, learning motivation and acceptance towards video games	Mixed methods. One-group pre-post mixed methods design collecting data at five-time points.	Qualitative: Discussions provided students opportunities to reflect on their game experiences and the current curricular topic as well as to practice media criticism. Quantitative: They improve perceived topic knowledge, learning motivation, and their acceptance towards video games
The use of video games for the teaching of ancient history in secondary education: An educational investigation	Dominations	Yes	Content knowledge and comprehension of historical time	Qualitative (with the use of rubrics and other tools to assess each domain). Interpretive-type research structured in different phases (search for classroom experiences, preparation, and design of research and didactic instruments, research in the classroom, and evaluation of the results)	Improves general motivation, content knowledge, and co comprehension of historical time
Playful blended digital storytelling in 3D Immersive eLearning Environments: A cost effective early literacy motivation method	Second Life	Yes	Perceptions of the teachers on student learning	Mixed methods. Questionnaires and interviews to explore teachers' perceptions on student learning	Teachers perceive that children acquired new skills, that the experience added to the students' perception of books and reading, and they found 3d worlds useful for facts recall & history understanding.

Besides the small number of projects using COTS (n = 11), most of them tried, to some extent, to measure their educational impact. Only one project (n = 1) was not measured.

The nature of these measurements was diverse, with some quantitative (n = 3), some qualitative (n = 3), and some using mixed methods (n = 4).

4. Conclusion and discussion

In this systematic literature review, we only found references for 78 relevant educational projects using games for teaching and learning geography and/or history in secondary education. The authors of this text have experience as elementary and secondary teachers and they have been involved in the Game Studies and GBL communities for years. This experience allows them to affirm that there are many more projects that are not covered in this kind of publications.

Most projects did not appear in the form of academic articles, but they were published in conference proceedings. Different scientific cultures among disciplines might explain these differences. For instance, Talja & Maula (2003) found that "journals and databases are likely to be used most heavily in fields in which directed searching is the dominant search method" (p. 673). This could explain, for instance, why Computer Science is usually more focused on conference contributions than Social Sciences disciplines, which would be more interested on journal publications.

Results could also mean that, even if academic journals might be considered more prestigious, teachers and researchers prefer to use conferences and social events to share their discoveries with the community. In this context, several authors have reflected on the problems of academic journals (Weiner, 2001) in comparison with other alternative formats such as conference proceedings which might better represent real practices (De Vries & Pieters, 2007). Going further, this should make us reflect on the pressure for publishing in high-impact journals and the competitivity generated around this pseudo-meritocracy. Moreover, it should be questioned to what extent this is contributing to a real knowledge transfer between research and educational practice. We have historically seen a lack of applicability of most educational research and on some occasions, the impossibility of generalizing results from a specific project to other contexts. This has led some authors to reflect about the "failure of educational research" (Miller, 1999, p. 17) or the "need [to] confront the sterility of past labors and take radical steps to conduct inquiry in more productive ways" (Reeves, 2000, p. 10).

Even though proceedings might better represent the work of teachers, we need to acknowledge the value of other practices that might take us closer to the idea of *design-based research* proposed by Reeves (2000). Authors, for instance have mentioned the importance of training courses and teacher professionalization when implementing game-based learning (Ketelhut & Schifter, 2011). Specifically, variables such as teacher efficacy in using the software, pedagogical issues, and school culture, seem to be critical.

It is surprising the lack of educational projects using COTS, besides all the scientific evidence highlighting its benefits. For instance, research made before this worked proved that using games such as *Europa Universalis* in history class improved students' knowledge about the 16th century (Egenfeldt-Nielsen, 2005) or that game *Civilization III* allowed students to better examine world history from 4000 BC to the present and stimulate problem-solving (Squire, 2004). As stated in the introduction, commercial games (and historical commercial games in particular) have shown to improve content acquisition (Clark et al., 2018) and many authors believe that they should be used more widely (Gee, 2014). However, it is important to remember that the game chosen is only one side of the story, being the role of the teacher and the activities proposed, the most important variables (Hanghøj, 2018).

Teachers interested in GBL have preferred to use educational games that help them to teach content or practice skills. Some authors have referred to this approach as *edutainment* (Egenfeldt-Nielsen, 2016) highlighting that these games are superficial and their quality and design is far from those students normally play (Facer et al, 2003). In fact, many times the explicit content contaminates students' experience and learners tend to perceive these uses as artificial instead of playful (Oceja, 2018).

Besides this lack of sociocultural approaches as mentioned by Gee (2014), some authors (Reng et al, 2016) point out that the most beneficial form of GBL occurs when students design their own games. These contributions, which are aligned with Papert's constructionist approach (1993) seem also very scarce as we only found four projects allowing students to design their own games. We find important to explore this possibility in depth, taking into account the numerous free tools available for working on digital game design (such as Scratch or Unity). Furthermore, making students design their own games physically is also an interesting and easier option for teachers.

Even though we found only a few projects using COTS or allowing students to design their own games, it was interesting that most of them tried to measure their educational impact. However, in future research, the rigor of these studies should be assessed thoroughly by applying a quality scale such as PEDro (Maher et al, 2003). It also would be interesting to expand this review by searching for specific games and finding any potential grey literature that gives us a more detailed picture of what teachers are doing in their classes.

In fact, we hope that this work contributes to a deeper understanding of how teachers are using games. We think that only by understanding games (both physical and digital) as cultural and artistic products with a capacity to move us and generate learning, we would be able to implement high-impact educational practices.

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Facilitating Social Inclusion of Migrant Students through Digital Games: Design Principles and Pitfalls in *Wanderers*

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Abstract: Schools are central in facilitating the inclusion of migrants and refugees in society. However, research from the LIM: Language, Integration, Media project has shown a lack of activities where students from various cultural backgrounds can come to know one other on equal terms. To meet this need, we designed a collaborative puzzle game – *Wanderers* – with the goal of facilitating low-stakes social interaction and cultural exchange between high school students with and without migrant backgrounds. This article outlines this design process and explores the design principles and pitfalls for digital games that support the social inclusion of migrants in a classroom setting. In the study, we use a design-based research methodology to address the research question: what design principles can be used to support social inclusion through cultural exchange in local collaborative play? We outline and discuss the following key design principles for games designed to facilitate social inclusion: 1) Facilitating cultural exchange through "safe topics"; 2) Promoting mutual dependency; 3) Diversity in representation and 4) A stimulating theme. We argue that these design principles can be used to design positive experiences that support the idea of inclusion as a two-way process. However, our discussion also shows how these design principles can also reinforce existing majority/minority configurations, and how conventional game design principles may fall short when applied in this specific context. The paper argues for the importance of low-threshold activities, such as small talk about food and holiday traditions, while also highlighting specific challenges in designing games for social integration.

Keywords: Games for inclusion, Collaborative games in classrooms, Game design principles

1. Introduction

In Norway, schools have been singled out as a main arena for social inclusion of refugees and other migrants (Norwegian Ministry of Justice and Public Security 2016). Yet, the institutional support for developing programs, activities and teaching materials to support this effort is lacking. In the research project *LIM: Language, Integration & Media* we collaborated with teachers, students, schools, and local municipalities to improve the integration of students with migrant backgrounds. From this project we learned that the shift between the introductory program for migrants into regular high school was critical, yet poorly supported. Furthermore, that students with migrant backgrounds had a strong desire to form friendships with Norwegian peers and to be part of the local community, but due to institutional and cultural barriers they often remained sequestered. To address these challenges, the collaborative puzzle-game *Wanderers* was designed to facilitate the introduction of students with different cultural backgrounds in a classroom setting, and to support social inclusion of students with migrant backgrounds. In this paper, we present the main design principles used in *Wanderers* and discuss how a playful and low-stakes approach has value in this setting, while also critically reflecting on potential pitfalls of the design.

Based on design-based research methodology (Reimann 2011), our discussion aims to highlight how well-intended design choices can have undesirable consequences, and to identify some design challenges related to this specific player group (students with and without migrant backgrounds) and context (classroom as space for social integration). Through our analysis we explore the following design strategies: 1) Facilitating cultural exchange through "safe topics"; 2) Promoting mutual dependency; 3) Diversity in representation and 4) A stimulating theme. We will briefly outline the design choices for each category and experiences from play sessions before reflecting on potential risks or unwanted consequences of these strategies.

2. Designing games for social change

Wanderers is designed as an accessible ice breaker activity where migrant and non-migrant collaborate. The game is designed with point-and-click type puzzles about language, food, and traditions in the students' country of origin to stimulate conversations about cultural background and identity. The game, and the research project it springs out of, is founded in an understanding of learning as inherently social, where the classroom culture, and relationship between students during play, are central both to learning and empowerment (Bleumers et al. 2012; Steward et al. 2013). Unlike many games that are used in a classroom setting, the goal of the game is not

to teach players about a given topic or as training of specific skills. Instead, *Wanderers* functions as a shared focal point and classroom activity where students with and without migrant backgrounds can participate on relatively equal terms with the explicit aim to create social ties between students. So, while the game is being played in a classroom, it may be better understood as a "game for social change" than a "game for learning", but these lines are blurry. For example, *PeaceMaker* (ImpactGames 2007) was designed to teach players about the conflict in the Middle East, as well as to promote dialogue between people regarding the situation in Israel/Palestine (Gonzalez and Czlonka 2010).

Games for social change has been used to trigger support for a cause (Bogost 2007), inform about ongoing conflicts (Bogost et al. 2010), and to understand complex situations such as climate change (e.g., Red Redemption 2011). Games may also be used to persuade the players of certain perspectives (Bogost 2007), or encourage civic engagement by showing children and youth how to make a change in the neighborhood (e.g., iCivics 2010). There are also examples of games designed specifically for cultural training, which hold promising results. A study on a boardgame for cross-cultural training indicated that "the game benefited participants' discussions and reflections regarding cultural awareness directly after the game session, and that they retained their attitudes and perceptions of cultural awareness better than participants of the non-game exercise" (Nyman Gomez and Berg Marklund 2018, p.81). The game "Cultural Awareness – Afghanistan Pre-deployment" was also generally well received as a modern tool for assimilating knowledge (Barbieri et al. 2014), and it has been suggested that commercial games, such as *Papers, Please* and *Tropico,* can be more useful in stimulating debates than serious games (Cleger 2015). However, there are also several challenges in designing and using computer games for intercultural exchange in classrooms. For one, commercial games are often developed by game developers from Western countries, white men are vastly overrepresented and often the only choice as protagonists, while characters with minority backgrounds are frequently stereotyped in negative ways (Williams et al. 2009; Penix-Tadsen 2019).

Like all serious games, games for social change must balance enjoyment with desired effect. Flanagan and Kaufman (2016) argue that for a game to be successful (in creating change), the player needs to have a meaningful (though not necessarily entirely positive) experience – prompting to prioritize experience over message. With well-designed gameplay, a game is also more likely to be played again and messaging will be stronger. Flanagan and Kaufman (2016) recommend the following embedded design techniques when designing games with a political or educational purpose (paraphrased by authors):

- Intermixing: Combine on-topic and off-topic content to avoid pushback and a sense of preaching, as games are considered a space for fun and play
- Obfuscating: Use game genres that direct the attention away from the "true" aim of the game (to cause change), and instead emphasize good game play. This also means avoiding overrepresentation of counter-stereotypical examples as they make the message too overt and reactivate the stereotype it attempts to hinder
- Distancing: Use fiction and metaphors to create a gap between the issue at hand and the players themselves
- Delayed reversal: Withholding/delaying information and problems in the game that deals with difficult or controversial topics.

Together, these design principles can be summarized as "Be less obvious", as they all highlight a need for distance or indirectness to controversial and/or challenging topics and emotions. It is not that games cannot deal with dark or difficult topics, but rather that serious games cannot lose sight of enjoyment and playfulness if the design is to be perceived as meaningful.

3. Methods

Both *Wanderers* (the game) and this paper are part of an interdisciplinary research project; *LIM: Language, Integration, Media,* that investigates pedagogical and technological ways to create innovative learning experiences and new competencies related to migration. In the project, researchers from different fields and backgrounds collaborated with local school partners and NGOs to explore how to foster integration and knowledge about migration in high schools and adult education centers for migrants in the 15 – 25 age range. Central in this endeavor was an understanding of integration as a two-way process where both those who are integrated – and those who are integrating – are subject to change.

The study was inspired by design-based research (Reimann 2011), a methodology with the aim of improving educational practices through iterative design in collaboration with practitioners. An important motivation for this game came from early focus group- and individual interviews conducted as part of the LIM project. This included eight focus group interviews with students of high-school age with participants from Eritrea, Syria, and Norway, and eight focus group interviews with teachers. These interviews identified the shift from specialized to ordinary classes as a critical junction where students received insufficient support. The migrant students had high hopes for new friends and communities when they finally joined the ordinary Norwegian schools, and were especially keen to make Norwegian friends. However, integration often failed, and they found themselves on the outside, or remaining in separate social groups. In addition, for students with migrant backgrounds it was important to be able to share their own culture, and several expressed a desire to talk about traditions and everyday life experiences from their country of origin. The main take away from the initial interviews was a need for activities and spaces to facilitate social interaction where cultural backgrounds were highlighted.

In line with design-based research, our insights regarding students' challenges based on the focus group interviews, in addition to a review of relevant literature, led us to the initial design of the game *Wanderers,* a narratively driven, puzzle-based game created in Unity. The game was designed by the first author in collaboration with computer science students, a music student, and hired artists. In this game, three high-school age students with different backgrounds (*Figure 1*) are invited onto the vessel *Wanderer* without knowing where they currently are and where they are going. Each time *The Wanderer* stops at a new location, the players will have to solve puzzles which will give them hints about their location. The puzzles are inspired by the countries Eritrea, Syria, and Norway, as many immigrants from Norway come from these countries. If they correctly guess which country they are currently in, they can advance to a new destination and new puzzles. The game draws inspiration from *visual novel adventure games* (Cavallaro 2009) *,* and the player follows the characters from a third-person perspective, shown in the game through drawn 2D character sprites. Through a 2D interface, the players navigate the game by clicking objects or navigation elements in the current scene. Dialogue and relevant information is presented to the player through textboxes. Since this was an early version of the prototype, the game was not voice acted, as this would both be time consuming and make it difficult to adjust the game dialogue at a later stage.



Figure 1: The main characters in Wanderers, Hani from Eritrea, Tarek from Syria, and Sara from Norway

In this study, we use our own game design experience as data, supported by observation data from the participants' playtest, focus groups and interviews, as well as our own experiences playing, studying and designing games that both does inclusion well and that leaves much to be desired. Our aim is to critically explore the initial design of the game, to aid future iterations of the game and to broaden the body of knowledge concerning games for social inclusion. We arranged a playtest conducted with 10 students at a local high school. These students had diverse backgrounds, mostly from African or Asian countries. Some students had arrived in Norway rather recently and transferred to the class from the introductory program for refugees, and thus had more limited Norwegian language skills, while others had grown up in Norway and spoke Norwegian fluently. The students played together in pairs or groups of three for an hour (the designated time for a complete play-through), and the playtest was followed up with a focus group interview. The game was also presented at several academic conferences and seminars for feedback from a wide range of people.

4. Facilitating cultural exchange through "safe topics": Safe for whom?

A core aim of *Wanderers* was to create a social and fun space for students with and without migrant background to engage with each other. From work in the *LIM* project we knew that students were lacking arenas and activities that facilitated meetings across cultures and institutions, but how to make a game about this? The answer was derived from interviews and workshops with migrant students where a desire to talk about cultural background and aspects of their lives before migrating to Norway was highlighted. This prompted the idea to focus the game on aspects like food, traditions, and celebrations. Using puzzle-based mechanics the game included puzzles like putting together the right ingredients to create dishes such as kebab karaz and baba ganoush, recognizing traditional dishes from Eritrea, and puzzles about the Norwegian celebration of Christmas. The playtests indicated these topics and puzzles worked well as a conversation starter. Players who had knowledge about traditional Norwegian food explained what unfamiliar dishes were to other players when solving a puzzle about celebrating Christmas (*figure 2*), and when solving puzzles involving creating traditional Syrian dishes, a player with Syrian background shared knowledge about how her family made the dishes and explained the name of the ingredients in Arabic. The focus group interviews after the playtest indicated that puzzles about food and traditions were seen as a good way to get to know other students.



Figure 2: Representing culture and traditions, here from the Norwegian Christmas celebration

Focusing the game on food, traditions and celebrations was primarily a way to stimulate discussions about cultural backgrounds. However, this focus was also chosen because food, traditions and celebrations were considered "safe topics". As the game is intended to be used as an ice-breaker activity, we wanted the play experience to feel safe and easy to pick up. Even with the potential danger of stereotyping an entire culture into a few dishes and celebrations, the playtests confirmed that being able to talk about something familiar – especially for the students with migrant backgrounds – was an enjoyable experience.

A problem with a focus on "safe topics", is that is displaces important, but more difficult, conversations about migration and cultural differences. From interviews and workshops, we knew that some students wanted to share their (often traumatic) experiences with both war and migration, while others did not want their migrant identity to be in focus and wanted to showcase the beauty and normality of their culture. We chose "safe topics" to create a space where students with migrant backgrounds were invited to speak about their culture without their culture being seen as "a problem". Looking back however, we wonder if this choice was made in part to make the game safe, not just for the students, but for ourselves. A recurring theme in the *LIM* project was how Norwegian students and teachers routinely postponed or opted out of key migration topics like the treatment of refugees, the horrors of war, and racism among Norwegians. The reason for disengaging with these topics was usually a variation of "needing to shield migrant students from their trauma", but a more critical reading showed that this also became a way for teachers and students to shield themselves from having to acknowledge the injustices experienced by their fellow humans. Similarly, it is likely that "safe topics" seemed like a good idea to us as game designers, in part, because it shielded us from having to deal with our players lived experiences of oppression and abuse.

While we still believe that icebreaker activities like playing *Wanderers* is fruitful for social inclusion, it primarily has value in giving students a shared activity that allows them to talk about their culture. For social inclusion to happen in a meaningful sense, more critical work migration and integration is needed in the classroom.

5. Promoting mutual dependency: Risking "a responsibility to know"

From interviews with teachers and students we identified a concern regarding asymmetry in collaborations between students with and without migrant backgrounds. Norwegian students had more power as they knew the language, the Norwegian school system, and likely had stronger digital skills. Students in focus groups further emphasized the importance of meeting each other on equal terms, leading us to adopt *mutual dependance* as a design strategy.

To achieve mutual dependence, the different puzzles were explicitly based on cultural knowledge (food, language, celebrations, traditions) from the selected backgrounds (Norway, Syria and Eritrea) (*figure 3*). The overall goal was to destabilize Norway and Norwegian as the default context and language, and to promote the cultural knowledge of migrant students as important and necessary. The playtest showed that this was largely successful as discussions happened both in, and across groups, as students were working their way through the puzzles where students who were, e.g., proficient in Tigrinya, had a chance to use their knowledge and be complimented for it.



Figure 3: A puzzle requiring knowledge of Tigrinya in order to place flowers according to their color.

While the use of culturally specific knowledge worked well in our playtests, centering the game on knowledge may also produce negative effects if migrant students do not possess the knowledge in question. Even if the topics are considered "safe", how solvable they are depends on the students schooling in their home country and how their particular family have chosen to celebrate (or not celebrate) common holidays. This means that what was intended to be empowering design has the potential to create vulnerability. The goal was to change the power balance in favor of the migrant student but may also give the students with migrant backgrounds a responsibility to know (Stivers et al. 2011). If this happens, the game may instead serve to reinforce the majority position of Norwegian students as the ones with knowledge (and power) where knowledge about other cultures is seen as the responsibility of "the other".

6. Diversity in representation: not stereotypical enough?

Diversity in representation was necessary to create a game that would appeal to students with different ethnic backgrounds and afford them equal opportunities of identification. Fair and thoughtful representation of ethnic minorities is important as they are rarely portrayed in computer games (Williams et al. 2009), and when they are they often rely on and support white supremacist views (Mazurek & Gray 2017). For example, when Arabic countries are included in games, it is often done in the context of games using armed conflict as a backdrop, and the games often portray Arabs as villains through racist stereotypes (Machin and Suleiman 2006; Šisler 2008).

To develop respectful and thoughtful representations, dialogue with the intended players from the ethnic groups involved is necessary. Games that have done this successfully, include *Never Alone* (E-line Media and Upper One Games 2014) where the developers collaborated closely with people from the Inupiat people that

they were portraying, and *Ayiti: The Cost of Life* (Global Kids and GameLab 2006) which was developed in collaboration with Haitian youth (Joseph 2007). As part of the design process of *Wanderers*, inspiration was drawn from interviews with students from Eritrea, Syria and Norway, as well as workshops where students designed their own games and discussions about what kind of representation they would like in games.

When developing *Wanderers*, the designer (first author) decided on a cartoony, manga-inspired style which is often seen in narratively driven, puzzle-based adventure games. This was in line with Flanagan and Kaufman's (2016) advice on obfuscating, where genre conventions are used to downplay the seriousness of the game. In addition, the game itself is inspired by Japanese-style adventure and puzzle games. Staying true to this art style was thus considered a choice that could provide for a more authentic gaming experience (Dickey 2005). A second reason for this graphical style is to *make the familiar strange.* Placing familiar topics in unfamiliar settings, such as fantasy settings, can help us see our own world more clearly or a new light (Pu 2012). This was also one of the reasons for why the setting for the game is a steam-punk inspired vessel that does not draw upon any cultural or geographical iconography.

Interestingly, the art style was well received by the students, yet several students wanted a stronger emphasis on cultural elements reflected in the characters appearance, such as including a character with hijab and national costumes. As repeated in many interviews and workshops, the students wanted their culture to be visible and wanted opportunities to talk about their backgrounds and experiences. However, their desire to include cultural artefacts like the hijab, also illustrates the challenge of creating fair and thoughtful representations. On one hand, creating a character with a hijab would be way to respect and recognize cultural heritage, while on the other – the same hijab could be interpreted as a stereotypical representation of "the other" (especially when considering that the game is developed by a white, Norwegian woman). Looking back on the process, we wonder if our desire to make the intentions "less obvious" also precluded us from giving the type of representations that migrant students desired.

7. A stimulating theme: The story that no one cared about?

Research on game-based learning has emphasized narratives and a stimulating fantasy and narrative to make the game interesting to players (Rieber 1996). A well-designed narrative may lead players to seek solutions to problems (Rieber 1996), intrinsic motivation for learning (Dondlinger 2007) and opportunities for 'reflection, evaluation, illustration, exemplification, and inquiry' (summarized in Dickey 2006, p.248). In line with this research, a narrative and fictional world was created and presented to players as an intro-cutscene and as dialogue between characters. When playtesting the game, however, we found that the extensive worldbuilding and storytelling worked against its purpose and pushed players away from, rather than inviting them into, the game.

In playtesting we saw several students simply clicking their way through dialogue, and instead focus on the puzzles, and we learned that for students who has Norwegian as a second language – the text was simply too long and too complicated. To address this, the narrative and dialogue was shortened in revision. It should however be noted that we did not initially consider the game to be text heavy, and the text was deliberately written in simple prose to be more accessible. By including narrative and worldbuilding the game ended up being less accessible to students who did not have Norwegian as their first language and clearly privileged the Norwegian students – contrary to our goal (cf. mutual dependency). Our experience highlights how seemingly obvious and agreed upon game design principles are challenged when designing for specific audiences and situations where multiple languages are used, and where not players have the same levels of literacy.

We are not arguing that narratives are not useful. A study by Bayeck (2019) showed that the games developed by the top African game studios in the region, specifically aiming to reach African audiences, used an expanded understanding of what narrative is, emphasizing gameplay, cut scenes, back stories, lighting, music and promotional material as part of storytelling. It is not that narrative is unimportant, but rather that text is a poor way to build characters and fictional worlds when attempting to support social inclusion of students with different literacy levels.

8. Summary and conclusion: Designing games for low-threshold intercultural meetings

In our discussion of design principles used in *Wanderers* we have emphasized the risks, mistakes, and potential pitfalls. Even though we, as designers and researchers, set out to create a game which was mindful of

representation, power balance and the wishes of the target audience, this article has shown how we still made mistakes in *all* areas. We will therefore argue that while games can facilitate intercultural meetings, the goal of social inclusion presents specific challenges that conventional game design ideals may be unsuited to solve.

The literature on educational games and games for social change tend to emphasize gameplay over message, encouraging designers to avoid the mistakes of edutainment and focus on making fun games, rich worlds, and engaging narratives. While we generally support this endeavor, our experience with *Wanderers* shows that these ideals have the potential to reproduce the power relations they attempt to challenge. For example, how building a rich narrative and fictional world could hinder mutual dependency and disengage students, when it was presented as text – as literacy is a core concern for the target audience. Or how basing a puzzle game on knowledge, even knowledge we consider to be general and "safe", can place the burden of knowing on the migrant students, giving the majority population free reign in their ignorance. Perhaps most importantly, and most insidious, is how advice about toning down political or ideological content encouraged us to shy away from conversations and topics that needs addressing. By choosing "safe topics" and representations that were not overly political, we succeeded in creating a game that was easy to pick up, encouraged discussions about cultural background and facilitated social bonding for new students in the classroom. However, we also ended up creating a game that may reinforce the general unwillingness of the white majority population in Norway to engage with the injustice of white supremacy, the unfair distribution of wealth between global North and South – and the mistreatment of migrants.

Wanderers has the potential to support students in engaging with each other's cultural background, and to do so in a relatively safe and playful way. Being aware of the potential risks and unwanted consequences of games brought into the classroom is thus of particular importance, as negative effects may be well mitigated when we know what they are.

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Recent Developments regarding Exergames and Individuals with Disabilities

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Abstract: Exergames are digital interactive games that require physical movements of upper and lower limbs by the users to achieve simulation with the game screen. Their effects regarding the maintenance of fitness levels and the improvement of their overall health, is proven to be positive. Due to attractiveness, they offer an innovative way to increase physical activity levels of individuals with disabilities. Exergaming may provide both entertainment and multiple benefits for the users while their engagement with the games may produce a positive mood state, socialization, improvement of well-being and good outcomes. Digital environment provides the possibility for the users to participate at the games on equal terms, regardless of academic performance and type of disability. Individuals with disabilities are less physically active compared to individuals without disabilities. As a result, their fitness levels appear to be lower compared to general population and that may cause cardiovascular diseases, diabetes, obesity and depression. The main reason for this is the absence of motivation to participate in physical education programs. Therefore, it might be meaningful to increase their physical activity levels using exergames. The purpose of this study was to explore the possible benefits of exergames on individuals with disabilities. To achieve this, an extensive research and record of relevant publications in recent years took place. Results indicate that exergames had positive effects on individuals with disabilities and although they should not replace their participation at exercise programs in real environments, they can be used in combination with exercise programs adapted to their needs. More specifically, results suggest that exergames are useful, attractive, and efficient tools for enhancing physical activity levels and attitudes. Additionally, studies reveal social, emotional, and motor benefits as well as improvements in communication skills contributing positively to the quality of their life.

Keywords: Exergames, Physical Activity, Exercise, Mood, Motivation, Disability

1. Introduction

Exergames are innovative games developed within an interactive environment for the user. They combine exercise with gaming, hence their name, exergames (exercise and games) (Sinclair et al., 2007). The term exergames or exergaming first appears in Collins dictionary (2007) and is used to determine the combination of gaming with exercise (Di Tore & Raiola, 2012). Exergames demand physical activity aiming to be part of virtual sports or interactive physical activities. The user is asked to achieve body movements according to the simulation game shown on the screen (Vernadakis et al., 2012).

According to Tan et al. (2016), exergames can be divided into three categories: 1) Living-room exergames such as Nintendo Wii (Kyoto, Japan) that require the user to perform exercise routines including dancing, aerobics, yoga, 2) Cardio machine exergames like Fish Game played on a rowing machine, with specific training equipment. Some exergames in this category contain virtual reality. 3) Mobile exergames with accelerometers, global positioning systems to track physical activity of the user and affect gameplay.

Individuals with disabilities usually embrace a sedentary lifestyle that can lead to the appearance of health problems such as cardiovascular diseases, diabetes, obesity, and depression. The main reason for this is the lack of motivation to participate in physical activity programs since they do not fully understand the benefits of exercise. Additionally, they enjoy participating in several activities like dancing, walking, bowling, training with weights combining in this sense exercise with the element of enjoyment, music, or goal-oriented games (Torrado, Jaccheri, Pelagatti & Wold, 2022).

A solution to this problem could be the investigation of successful methods for their encouragement to participate at physical activity programs (Millana et al., 2022). Technology may support individuals for self-managing chronic conditions. Exergames are challenging for individuals with disabilities and can be possibly used as an alternative exercise program for the improvement of their fitness levels and motor function (Silva et al., 2017).

According to the above discussion, the main goal of the present study was to scan and review related studies regarding exergame technology and their effects on individuals with disabilities. The results of this study are expected to offer literature review regarding recent developments in exergames technology and their applications on interactive interventions for individuals with disabilities.

2. Research Method

Articles that met the following criteria were selected for the review: a) Should be published in English; b) Should be dated during the decade 2013- 2021; and c) Participants should be limited to individuals with disabilities and the use of exergames. Person, concept, and context (PCC), as recommended by Peters et al. (2015), was used to structure the inclusion criteria as follows: person-severe mental disorder (schizophrenia), intellectual and developmental disability (autism spectrum disorder, down syndrome), motor disability-cerebral palsy); concept-exergames; and context-individuals with disabilities, English language. The inclusion and exclusion criteria were used to refine the search strategies and provided a framework for searching the literature (Table 1). A scoping review of exergames research showed a constant growth over recent years and positive progress towards adapting new technologies in special populations. The aim for conducting the scoping review was to identify and map the available evidence (Arksey & O'Malley, 2005). The stages of the framework we adopted for conducting this scoping study were the following: Stage 1: identifying the research question, Stage 2: identifying relevant studies, Stage 3: study selection, Stage 4: charting the data, Stage 5: collating, summarizing and reporting the results (Arksey & O'Malley, 2005).

Stage 1

The purpose of this scoping review focuses on the effects of exergames on individuals with disabilities aiming to target certain characteristics that are important for them to become more physically active. The research question to be answered was:

- What is known from the existing literature regarding the effectiveness of exergames on individuals with disabilities?

Stage 2

A literature review took place from February 2022 to April 2022 and the present study started looking at the main database research engine (i.e. ScienceDirect, PubMed, Google Scholar) to collect related articles. The selection process carefully identified the articles that focused on the related exergaming issues on individuals with disabilities. Accordingly, researchers used several key words such were exergames and disability. More specific, exergames and schizophrenia, intellectual disability, autism spectrum and cerebral palsy to identify the most relevant articles. We focused on specific disabilities that involved intellectual and motor disability, and severe mental disorder.

All selected articles were checked by the researchers to make sure that the main issue of each study was relevant to the goal of the present study. For this reason, several criteria were set for filtering the selected studies, including that the main goal of each study should include exergames and individuals with disabilities. Stage 3
This process resulted in 50 articles with a final selection of 10 articles (Table 2) that were considered for analyses in the present study.

Stage 4

The data that we charted were entered into a 'data charting form' using the database program Excel. We recorded information as follows: 1) Author(s), year of publication. 2) Intervention type; duration of intervention. 3) Study populations. 4) Aims of the study. 5) Methodology. 5) Outcome measures. 6) Important results.

Stage 5

The literature was organized thematically according to different types of disability. We recorded our findings and summarized basic characteristic of all studies included information such as: interventions, sample sizes, participants, research methods, outcomes, evidence relating to effectiveness.

3. Literature Review

3.1 Autism Spectrum Disorder (ASD) and Intellectual Disability (ID)

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder associated with deficits in social interaction, emotional reciprocity, communication, motor skills and cognitive functions accompanied by impairment in imagination and limited interests (Lima et al., 2020). Exergames for individuals with ASD have been designed to

enhance social, communicative, and narrative skills (Bernardini, Porayska-Pomsta & Smith, 2014), to learn the appropriate body postures and to support motor coordination (Caro et al., 2017). Their design follows a methodology that is user centered to support developmental skills for individuals with ASD. Additionally, they offer interaction without the need of any other device but just body movements by the user to control the game. Examples of such games are Astrojumper (Finkelstein et al., 2013) and FroggyBobby (Caro, Tentori, Martinez-Garcia & Zavala-Ibarra, 2015; Caro et al., 2017). Astrojumper is a fascinating virtual reality exergame that demands body movements (touchless interaction) to avoid obstacles, collect bonuses and fight battles. Many individuals with ASD, managed to achieve high levels of activity, participate to physical activities, and confront behavioral problems and health issues. FroggyBobby is a Kinect-based exergame, designed to support visual-motor skills for individuals with ASD (Caro et al., 2015). It is efficient for the users' participation and motivation for executing exercises aiming to improve visual-motor coordination, increase accurate aimed limb movements of children with severe ASD (Caro et al., 2017) as well as for the motivation of adults with developmental disabilities to execute exercises on visual-motor coordination (Caro et al., 2018).

In this regard, the study of Caro et al. (2020) aimed to compare two exergames for the support of visual-motor coordination of highly functioning individuals with ASD. The first exergame was designed for individuals with ASD and the second for neurorehabilitation. FroggyBobby and Kinect Monsters exergames were used on high functional individuals with ASD, ages 4- 15, including 8 children (all boys 7 years old) and 6 adolescents (5 boys and 1 girl, 12.8 years). The 12 participants had previous experience with videogames like Mario Bros, Minecraft using PC, Nintendo or Playstation consoles. To measure the users' experience with exergames, the Core Module of Game Experience questionnaire (GEO) (IJsselsteijn, Poels & de Kort, 2008) was used and for the measurement of satisfaction, Fun Toolkit instrument (Read, 2008) was used. Each participant executed specific exercises of visual-motor coordination for a total of 60 minutes (30 minutes for the right hand and 30 minutes for the left). Results indicated that there were differences between the two exergames, with the one designed for ASD to excel in comparison to the game that was commercially available. Significant differences were detected on limb movements as participants playing the exergame designed for ASD, scored higher on aimed limb movements (limb movements aimed at a visual target). In conclusion, even though both exergames can be used as possible tools for the support of visual-motor coordination on individuals with ASD, the exergame designed for individuals with ASD was reported to be more fun and could possibly motivate them for further use in the future.

Finkelstein et al. (2013) studied physical activity and motivation levels for ten individuals with ASD (ages 8- 20), ranging from low functioning to high functioning, as they played with the Astrojumper game. Participants had two separate sessions with different parameters (1st session three screens, 2nd session single screen), playing the game for 45 minutes. After the first session they completed a post-experiment questionnaire and after the second session, a short survey regarding their involvement with Astrojumper game, to compare the two versions of the game display. Results showed that most of the participants succeeded vigorous physical activity levels. Moreover, participants mentioned high levels of enjoyment and committed to exercise more frequently with such games.

Intellectual disability is characterized by significant deficits in cognitive function as well as in adaptive behaviors in social and motor skills. The level of intellectual disability varies but is always linked to cognitive impairments. The aim of the study of Syropoulou et al. (2021) was to investigate the factor structure and cross-cultural validity of the self-report questionnaire of Ho et al. (2017), on a sample of Greek elementary students with mild intellectual disability who used Virtual Reality exergames. The questionnaire included five scales: namely self-presence, mood experience, game enjoyment, attitude toward exergames and preference for future involvement with gameplay. The participants were 103 students, ages 9- 12 (boys=52.4%, girls=47.6%). The intervention program included four sessions over two weeks, where participants played with the Carnival Games (PlayStation VR platform). After the completion of the intervention, participants individually completed a self-report questionnaire with the researcher's assistance. Their results showed that the model was appropriate, and the instrument seems to have good internal consistency, appropriate convergent and discriminant validity. They supported the psychometric integrity of the questionnaire by Ho et al. (2017) on children with intellectual disability. Perceptions on the positive effects of exergames were positively linked with the participants' preferences for future involvement with gameplay. Enjoyment and positive mood state presented high scores. More specifically, participants presented high engagement with exergames (level of presence), when the element of entertainment was present, and they showed positive attitudes (joy and mood experience). In conclusion, exergames were useful and efficient tools for the improvement of attitudes and behaviors towards

physical activity, while presence, mood and enjoyment mentioned as important factors that should be investigated in future studies.

Individuals with Down Syndrome (DS) often reveal low levels of physical activity, muscle strength, motor proficiency impairments (balance and postural control) and limitations in motor function. In the same line Silva et al. (2017), investigated the benefits of an exercise program with Wii, for fitness, functional mobility, and motor proficiency for adults with DS. The sample consisted of 27 adults with DS, ages 18- 60 who were randomly separated to an experimental group who engaged with Wii (n=14) and a control group (n=13). Those in the experimental group participated at a two-month program with Wii, three times per week for 60-minute sessions. The program included games for the improvement of aerobic capacity, balance, and isometric strength through the following games: free run, heading, table tilt, snowboard slalom, tightrope tension, hula hoop, balance bubble and penguin slide. Additionally, participants completed several sports and dancing games targeting aerobic endurance (Wii Sports, Wii Sports Resort, Wii Fit and Just Dance 2), including swordplay, boxing, cycling, table tennis and Just Dance 2. Participants were assessed with anthropometric measures, fitness, functional mobility, and motor proficiency. The control group took part at the daily activities of the day care center such were rehabilitation, everyday life skills and art activities. Results showed that exercise with Wii may contribute to the improvement of functional mobility as well as offer fitness benefits, aerobic endurance, speed and agility, lower extremities and abdominal strength, speed of limb movement and flexibility. Moreover, there was significant increase in muscular strength. In conclusion researchers proposed that exercise with Wii may be efficient for individuals with DS and may become an alternative solution for their regular engagement with physical activities, since games are fun and the necessary equipment is affordable.

3.2 Schizophrenia

Individuals with schizophrenia embrace a more sedentary lifestyle compared to the general population (Vancampfort et al., 2012). The sedentary lifestyle is connected to multiple cardiometabolic comorbidities (Vancampfort et al., 2013) and daily dysfunction (Kimhy et al., 2015). During recent years, many efforts were made for their participation in interventions with aerobic exercise to increase their fitness levels. Technology evolution during the last decade led to the development of games that promote physical activity that promote a more active lifestyle by transforming physical activity to recreation (Lieberman et al., 2011). Up to date, there is just a small number of studies for the assessment of the use of exergames on individuals with schizophrenia (Leutwyler et al., 2012; Patsi et al., 2012).

Patsi et al. (2016) investigated the perceptions of individuals with schizophrenia on exergames. Participants included 8 individuals with schizophrenia, ages 35- 63 (5 males, 3 females), who lived at a psychiatric hostel and were in the process of reintegration in society. Nintendo Wii exergame was used with the following games: tennis, boxing, ping pong, fencing and biking. An individual, structured interview with the participants' psychiatrist followed the completion of the study. The duration of the intervention with Nintendo Wii Sports and Wii Sports Resort exergame was 18 weeks, 3 times a week for 45 minutes. Results showed that all participants had positive perceptions toward exergames. All of them reported that they experienced positive emotions and had a good mood during game play.

According to Kimhy et al. (2016) the benefits of exergames on individuals with schizophrenia were investigated. The sample of the study included 41 individuals with schizophrenia (ages 26- 46), 16 of which were the experimental group and 17 the control group. All participants were outside patients of a mental clinic in New York. From the experimental group, 13 participants fully completed the 12 weeks program and additionally received the typical psychiatric care. The rest, 3 participants attended only the first week of the intervention. From the control group, 13 participants received the typical psychiatric therapy for 12 weeks. The rest, 4 participants quit the program. The program included three sessions of one hour per week, for 12 weeks. The exercise protocol for each session included a 10-minute warm-up, individual exercise with the game for at least 45 minutes and recovery for 10 minutes. A trainer was present during all sessions for direction and support, along with a researcher assistant to record all data. Xbox 360 Kinect console was used with the game "Your Shape Fitness Evolved 2012", which was an interactive physical activity for the whole body combined with two treadmill machines, a stationary bike, and an elliptical machine. Results indicated that the mean participation of individuals of the experimental group was 28.5 at the 36 programmed sessions of the 12 weeks (79%; 2.4 sessions per week). Most of the exercise time was dedicated to Xbox Kinect (39%), treadmill (32%), stationary bike (13%), elliptical machine (13%) and guided exercise (3%). Participants accepted the game and had fun with it since they used it more compared to other exercise tools. Therefore, the aerobic capacity of the experimental

group was increased while no benefits were found for the control group. Their results strongly supported that exergames contribute to an active lifestyle since physical activities are enriched with fun.

3.3 Cerebral Palsy (CP)

The term Cerebral Palsy (CP) is used to describe a group of disorders resulting from brain injury with its main characteristic being the relation to motor dysfunctions. Sometimes, but not always it may come together with intellectual disorder. Macintosh et al. (2017) attempted to design a suite of exergames, by using especially designed recumbent bicycles that were connected online with a digital game world for young individuals with CP at Gross Motor Function Classification System (GMFCS) level III (Rosenbaum et al., 2008). Participants consisted of 10 young individuals (5 females, 5 males) with CP, age 10- 16, who enrolled in a 2-week gross motor camp, with GMFCS level II (unassisted walking) or III (mobility aids needed for walking). They all were able to use a hand-held videogame controller. Users executed cyber cycling to move their avatars within the digital world and played mini games. Exergaming sessions took place in groups of five participants each, with at least two participants at each GMFCS level per group. Data recorded for each session included Heart Rate (HR) and gaming data. Participants wore a Polar H1 HR monitor while sitting at an exergaming bicycle with a specialized seat equipped with a seatbelt and lateral supports connected to a PC Gamer Bike Mini and a computer. They played each day three adapted mini games (Wiskin Defense, Biri Brawl, Gekku Race), for 10 minutes each game and a 2--5-minute rest between games. Participants filled out questionnaires between games. Results showed that while all participants enjoyed playing with exergames, participants with GMFCS level II, scored higher and dedicated more time with above 40% Heart Rate Reserve (HRR) in relation to the participants of level III. These differences present the need for continuous refinement regarding gross motor skills and specific balance skills in exergames. Successful engagement with games may contribute to the increase of motivation and opportunities for exercise to improve cardiovascular capacity and social interaction. Researchers also mentioned improvements in cardiovascular capacity and physical wellness. In conclusion, exergames are fun tools that promote moderate intensity exercise and a rehabilitation tool assisting in a way continuous participation in the future.

A recent study (Cardenas et al., 2021) assessed the possibility to use a cycling-based exergame for children with CP, following an orthopedic operation of the lower limbs and investigated its effect on pain and wellness. For this reason, a group of clinicians and computer scientists designed the Liberi Exergame especially for children with CP, who were ambulatory and functioning at Gross Motor Functional Classification Scale (GMFCS) I-III. This interactive, multi-player exergame, included seven different mini games and was powered by pedaling on a stationary bicycle and game-controllers, giving the children the opportunity to exercise while playing all together. The engagement of children with the stationary bicycle had obvious improvement on their psychosocial health, emotional wellness, and gross motor function for non-operative ambulatory children with CP, as well as benefits for motor function, pain and daily life activities for adults following total hip replacement (Demuth, Loretta & Fowler, 2012). Participants included 10 children with CP, five of whom received physical therapy and were the control group (3 males and 2 females, 14±2.8 years) and the rest five were the experimental group (3 males and 2 females, 13.8±2.9 years). They all participated at 15 sessions with exergames and physical therapy for a total of three weeks. Two questionnaires were used to measure pain, FPS-R and Patient Reported Outcome Measurement Information System Pediatric Pain Interference (PROMIS-PI). Participants were asked to point the face that indicated the intensity of pain felt over the last seven days. (Hicks, 2001; Varni et al., 2010). Additionally, the KIDSCREEN-27, a standardized health-related quality of life questionnaire, was used for Physical Well-Being, Psychological Well-Being, Autonomy and Parents, Peers and Social Support and School and Environment (Ravens-Sieberer et al., 2014).

Results indicated that children in both groups experienced less pain over the 3-week study period. Participants in control group reported that pain increased during the study while those in the experimental group reported that pain did not increase. They also noticed significant improvements in mental and physical well-being over the period of 3 weeks. Engagement with exergames demonstrates the potential to improve pain and pain interference over the 3 weeks. In conclusion, researchers noticed that the inclusion of exergames is possible within the therapy of children with CP and that there is potential for improvements on both pain and well-being.

4. Discussion

The purpose of the present study was to present a review of recently published literature on the use of exergames by individuals with disabilities. A literature review of 10 studies published from 2013 to 2021 was conducted. Results indicated that the engagement with exergames had mental and cognitive benefits on

individuals with disabilities, including the increase of social interaction and motivation. According to Staiano and Calvert (2011), the engagement with exergames may increase motivation to participate in physical activities.

There are many devices that offer assistance and easy access for individuals with physical or cognitive disabilities, to improve their skills and acquire autonomy and better quality of life. Exergames for individuals with ASD are designed to enhance social, communicative, and narrative skills (Bernardini et al., 2014), to learn proper body postures and to support motor coordination (Caro et al., 2017). Caro et al. (2020) reported that exergames could be viewed as possible tools for the support of visual-motor coordination for individuals with ASD. They supported that exergames specifically designed for individuals with ASD, provided fun experiences and may possibly motivated them to continue using them. Moreover, Syropoulou et al. (2021) noticed that exergames were useful and effective tools for the improvement of postures and attitudes of individuals with intellectual disability.

Exergames are attractive tools, motivate individuals and positively contribute to their rehabilitation. For example, exergames like Nintendo Wii and Xbox Kinect can be used to increase activity levels and be part of rehabilitation process for individuals with disability. It is possible to offer multiple benefits on patients' therapy (Taylor et al., 2011) and in this regard Patsi et al. (2016) noticed that participants with schizophrenia presented a very good mood and positive attitudes toward exergames. They reported that they would choose to participate in sports within the real environment and that their engagement with exergames motivated them to get involved with new sports. Similarly, Cardenas et al. (2021) supported that the inclusion of exergames is possible within the therapy of children with CP. In the same line, Macintosh et al. (2017) examined the use of exergames on individuals with CP and may improve pain and wellness. Results showed that the successful engagement with the games probably contributes to the increase of motivation and opportunities for exercise aiming to improve cardiovascular health and social interaction.

In conclusion, exergames are attractive tools for the improvement of daily levels of physical activity of individuals with chronic physical disabilities (Hurkmans et al., 2010). The present study presented studies regarding exergames and individuals with disabilities. Results indicated that the use of digital environment offers the possibility for individuals to participate at the games on equal terms regardless of academic performance and type of disability (Russell & Newton, 2008). Exergames can be possibly used as an alternative to exercise programs for the improvement of their fitness levels and motor function. Because of their attractiveness, the games offer the user an alternative way to increase fitness levels, contributing in this way on the improvement of their health (Lam et al., 2011). They are already used as rehabilitation tools on individuals with disabilities of all ages and could become an alternative solution for their regular engagement with physical activities. Therefore, exergames have positive effects on individuals with disabilities and even though they cannot replace exercise programs in real environments, they can be used in combination with exercise programs adapted to their needs. In this regard, studies with the long-term effectiveness of exergames may conducted, aiming to motivate individuals with disabilities to embrace an active lifestyle with or without the incorporation of exergames.

Table 1: Inclusion and exclusion criteria for a scoping review of articles about studies of the use of exergames in individuals with disabilities

Criterion	Inclusion	Exclusion
Language	Published in the English language	Non English articles
Time period	January 2013-January 2022	Articles published outside this time frame
Population focus	Children and Adults experiencing some type of disability (e.g. a) mental disorder-schizophrenia, b) intellectual and developmental disability-autism spectrum disorder , down syndrome, motor disability-cerebral palsy)	Participants experiencing other conditions (e.g., depression, stroke, rehabilitation, special educational need, motor disorders, visual impairment) and typical population
Study focus	Use of exergames (some with virtual reality)	Studies not primarily focused on exergames (e.g., virtual reality games and education) or studies that utilized TV or Web technology
Literature focus	Articles about studies that used exergames as interventions in populations with individuals with disabilities, to export outcomes and benefits	Review articles including systematic reviews, meta-analyses, meta-syntheses, narrative reviews, rapid reviews, critical reviews, integrative reviews, and the gray literature such as blogs, commercial

Criterion	Inclusion	Exclusion
		Web sites, opinion articles, commentaries, and information sites

Table 2: Exergame studies and Individuals with Disabilities

Author(s)	Participants	Disability	Exergame(s)	Results
Caro et al., 2020	14 (ages from 4 to 15)	Autism Spectrum Disorder (ASD)	FroggyBobby, Kinect Monsters	Both exergames sustained attention, elicited positive emotional expressions, motivated participants to perform independent visual-motor coordination exercises
Caro et al., 2017	7 (ages from 7 to 10)	ASD	FroggyBobby	Maintenance of attention, reduction of aimless limb movements
Finkelstein et al., 2013	10 (ages from 8 to 20)	ASD	Astrojumper	Vigorous physical activity levels, high levels of fun
Caro et al., 2018	10 (ages from 23 to 36)	Developmental Disabilities (DD)	FroggyBobby	The exergame motivated adults with DD to perform visual-motor coordination exercises
Silva et al., 2017	27 (ages from 18- to 60)	Down Syndrome (DS)	Nintendo Wii Sports, Wii Sports Resort, Wii Fit, Just Dance 2	Improvements of functional mobility and fitness benefits
Syropoulou et al., 2021	103 (ages from 9 to 12)	Intellectual Disability (ID)	Carnival Games (PlayStation VR platform)	Enjoyment and positive mood state presented high scores
Kimhy et al. 2016	41 (ages 26 to 46)	Schizophrenia	Xbox 360 Kinect	The aerobic capacity was increased
Patsi et al., 2016	8 (ages from 35 to 63)	Schizophrenia	Nintendo Wii Sports, Wii Sports Resort	Positive perceptions toward exergames
Cardenas et al., 2021	10 (ages 11 to 17)	Cerebral Palsy (CP)	Liberi	Improvements in mental and physical well-being
Macintosh et al., 2017	10 (ages from 10 to 16)	CP	Cyber Cycling	Improvements in cardiovascular capacity and physical wellness

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Designing a Game to Promote Equity in Cybersecurity

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Abstract: Cybersecurity faces a persistent problem with attracting and retaining diverse workers. Most exposure to cybersecurity as a discipline tends to come through formal experiences in higher education, often requiring extensive prior experience with computer science content. Therefore, informal learning environments that can serve to both introduce youth to concepts found within cybersecurity, as well as aiding them in building identities as the type of person who can 'do' cybersecurity, may be able to advance the goal of diversifying the field. Game-based learning is an effective approach for attracting new learners to specific domains of knowledge in informal contexts. Players who might not otherwise think of themselves as being capable participants within a field can use the structures and supports commonly found in well-designed digital games to build a personal identity as a novice practitioner of that domain. Previous work has found that while cybersecurity is represented in some commercial games, the depiction tends to be either superficial, or when there is a deeper engagement with content, tends to represent a stereotypical personage of a cybersecurity professional. In this paper, we present a digital game, called *HEX of The Turtle Islands* (*HEX*), designed to introduce players from historically underrepresented populations to the domain of cybersecurity. *HEX* leverages several gameplay elements to immerse players in a learning experience centered on cybersecurity: rich, multi-layered narratives; building player self-efficacy and identity within the domain of cybersecurity through challenges rooted in concepts that are authentic to the field; and making the game broadly accessible in terms of technology and design. In introducing HEX, we discuss how the design of the game can broaden participation in cybersecurity and conveys authentic cybersecurity concepts to players. Drawing from 2 years of playtesting data with a diverse group of youth play testers, we discuss both challenges and opportunities for introducing underrepresented youth to cybersecurity through play.

Keywords: game-based learning, cybersecurity, game design, self-efficacy, equity

1. Introduction

Cybersecurity is an interdisciplinary practice, which bridges people, technology, and networks that comprise our modern information society (Bambauer et al., 2021; Burley et al., 2017). However, cybersecurity faces a persistent problem with attracting and retaining diverse workers (Reed & Acosta-Rubio, 2017) - namely women, people of color, indigenous populations, workers with disabilities, and other minoritized populations. Most exposure to cybersecurity as a discipline tends to come through formal experiences in higher education, which often require significant prior computer science coursework, where these populations have been historically excluded (Burrell & Nobles, 2018; Dark, 2002). Other technical disciplines also have a 'bottleneck' problem, where the formal pipeline through education is gates by experiences that are alienating to minoritized students and women (Shumba et al., 2013). The bottleneck issue in cybersecurity is compounded by the way that it is typically taught as a capstone in computer science, meaning learners are only introduced to it at the tail end of their academic careers (Reed & Acosta-Rubio, 2017). While there are several informal initiatives to broaden cybersecurity participation in primary and secondary education (e.g. Gen-Cyber), these are often restricted to in-person events that are limited in scope (Ricci & Gulick, 2017; Tobey et al., 2014). These initiatives, which are often structured as game-like experiences, are shown to be effective at increasing interest in cybersecurity, but are necessarily limited by time, space, and access (Wee et al., 2016). Therefore, informal learning environments that can serve to both introduce youth to concepts found within cybersecurity, as well as aid them in building identities as people who can 'do' cybersecurity are appealing to the larger goal of diversifying the field (Jin et al., 2018).

Game-based learning has been shown to be effective at introducing learners to self-efficacious experiences (Connolly, et al., 2012; Gee, 2009; Ketelhut, 2007), and allow players to engage with content area skills and knowledge (Clark et al., 2016; Holbert & Wilensky, 2017). Relatedly, games are currently widely enjoyed by youth of all backgrounds and demographics (Duggan, 2015; Juul, 2010). Therefore, there is great potential in creating cybersecurity gaming experiences that can serve as an introduction to the field, thus diversifying the profession

as a whole. In this paper, we report on our efforts to design such a game for the field of cybersecurity, titled *HEX of the Turtle Islands* (*HEX*), and pursue the following overarching research question: *How can the affordances of digital games and play be used to broaden participation in cybersecurity?*

2. Promoting Equity in Cybersecurity and Game Design Implications

As with other technical disciplines, cybersecurity professionals are usually trained through formalized coursework in higher education. Like other career paths, the trajectory of a cybersecurity professional is unique to the field itself, influenced by both formal and informal experiences (Cannady, Greenwald & Harris, 2014) as well as the background and identity of the learner (Calabrese Barton et al., 2012). Due to the interdisciplinarity nature of cybersecurity and its academic positioning as a subfield of computer science, it is often not taught formally until the upper levels of computer science higher education (Dark, 2002). As a result, only students who have completed years of computer science coursework have the opportunity to learn about cybersecurity courses. This has direct implications for the diversity of the field, as computer science has long struggled to recruit and retain a student body the reflects the racial, socio-economic, and gender demographics of the larger population (Zweben et al., 2020). Game-based learning presents a way to address this issue by introducing learners to fields where they are underrepresented, allowing them to build self-efficacy and identities within those domains (Ketelhut, 2006), experience domain-authentic representations of concepts (Holbert & Wilensky, 2017), and to build identities as practitioners within those domains (Gee, 2006; Squire, 2006). Previous work has found that games often use cybersecurity superficially as a visual or narrative aesthetic, but infrequently convey authentic concepts from the domain (Coenraad et al, 2020; Gestwicki & Stumbaugh, 2015). In terms of the goal of diversifying the cybersecurity workforce, Coenraad et al. (ibid) also found that in games that have more conceptually accurate representations of cybersecurity, there is also a lack of diversity in representation of the player's avatar and in non-player characters. Thus, for games to serve as a mechanism to broaden participation in cybersecurity, they need to more authentically engage players with concepts in cybersecurity and do so in a way that promotes equity in the cybersecurity workforce.

Given the goal of this work, we pursued the design of HEX with three primary design considerations: (1) Multiple Intertwined Narratives, (2) Authentic Representations of Cybersecurity and Computational Thinking Concepts, and (3) Tying Narrative and Puzzle Elements Together Through Exploration as a Game Mechanic. Since our goal is to appeal to populations who are not well represented in cybersecurity (thus expanding equity), **multiple Intertwined Narratives** can serve as 'hooks' to draw a broader array of players into the game. Narrative is an essential element of game-based learning in terms of driving player immersion and engagement (Jemmali et al., 2018; Naul & Liu, 2020), however narratives that are either alienating or distracting can have negative impacts on learning outcomes (Dickey, 2011). Game design literature indicates that many of the youth in our target demographic prefer game narratives that focus on the idea of helping others (Graner-Ray, 2004). Therefore, *HEX*'s narrative includes three intertwined narratives: a central story related to helping and rescuing characters who are close to the player, a related narrative about maintaining the ecological health of a unique island ecosystem, and an overarching narrative relating to a growing cybersecurity threat from a shadowy corporation. Given that cybersecurity historically attracts individuals who are already interested in computer science (Center for Cyber Safety and Education, 2017), we wanted to create numerous opportunities for players to both see themselves as capable of tackling cybersecurity challenges, and to use the embodied nature of gameplay (Squire, 2006) to connect their actions in-game with their personal identities. Thus, it is important the game have **Authentic Representations of Cybersecurity and Computational Thinking Concepts.** This has informed the design decisions of embedding cybersecurity activities into the two narrative themes to provide motivation to pursue those themes, to provide significant scaffolds for the cybersecurity activities, and to provide vicarious experiences through NPC 'friends.' The game supports identity formation through the implementation of a dynamic avatar system to allow the player to create a projective identity within the game world (Birk et al., 2016; Gee, 2007). Finally, the game seeks to **tye Narrative and Puzzle Elements Together Through Exploration as a Game Mechanic.** Given the interdisciplinary nature of cybersecurity (Bambauer et al., 2021; Burley et al., 2017), we have made a mechanical decision to incorporate both narrative and conceptual elements into a rich, explorable world, which ties together both the social and technical aspects of cybersecurity.

2.1 Introducing HEX of the Turtle Islands

HEX is a game that combines rich narrative, puzzles and challenges rooted in cybersecurity concepts, and gameplay focused on exploration. In *HEX,* players take on the role of a youth participating in a summer work study program investigating recent changes in the ecology around a remote island chain called *The Turtle Islands*. During their trip, their boat is boarded by pirates, and the crew is kidnapped, requiring the player to investigate

a larger conspiracy involving the shadowy corporation known as HEX. The players encounter cybersecurity challenges that they must solve to find out what is happening, rescue the crew, and help save the world.

The game takes the form of a 2-dimensional isometric adventure game, with a design and perspective similar to the *Legend of Zelda: A Link to the Past* (Nintendo, 1991). The current build of the game focuses on one island of the game and provides a tutorial for basic game mechanics, sets up the three primary narrative strands, and introduces players to puzzles that focus on ciphers (Fig 1.a), computational logic (Fig 1.b), pathing (Fig 1.c), modular arithmetic (Fig 1.d), and non-conceptual puzzles such as box pushing (Fig 1.e).

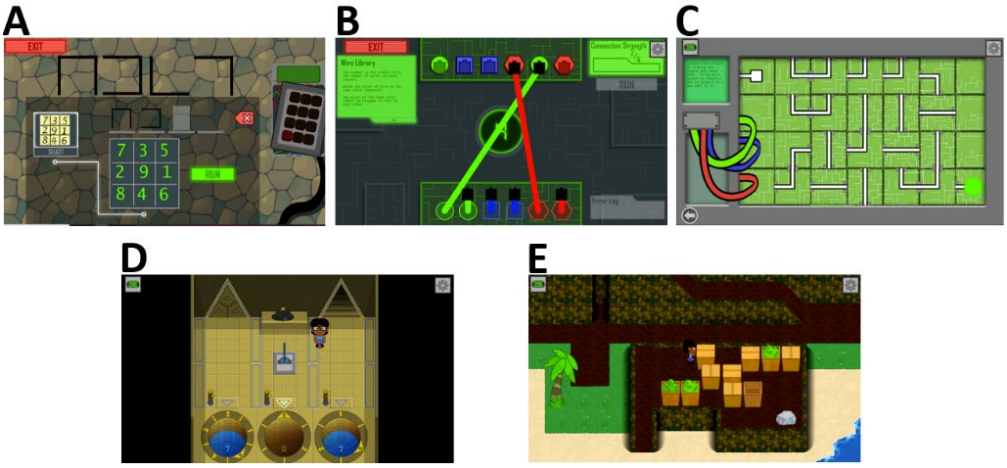


Figure 1: The five primary puzzles in the current build of the game. Label A is a simple cipher that matches numbers on a keypad to shapes on a 3 by 3 grid, B is a wire matching puzzle that is based on computational logic, C is a pathing puzzle where players must connect two sides of a circuit, D is a modular arithmetic puzzle where players use concepts from modular arithmetic to balance water between three wells, and E is an example of an environmental obstacle (in this case pushing boxes to reach an objective)

3. Playtesting Methodology and Data Analysis

HEX has been play tested by 31 participants between the ages of 10 and 16 through in-person and online playtesting sessions. Our target age range is 10 to 13, and data from this age range was prioritized in our preliminary analysis, however due to our recruitment and data collection taking place in public libraries we increased the age range to 16 to allow for older siblings who may be responsible for their younger siblings' aftercare to participate as well. Participation was incentivized with a $15 Amazon gift certificate, and both parental consent and child assent was collected for each participant. The demographics of our sample are reported in Table 1 below. For our findings we include in-text notation to describe participants (e.g. Female, 12, African American), along with a pseudonym assigned to match the participant's stated gender. For each session we collected the participant's play data, which was recorded through a novel method of data collection where players were asked to frame their responses to the game as live-streaming (Pellicone et al., 2022). Play sessions averaged around 45 minutes and included both player commentary and recorded gameplay. At the conclusion of the session, we asked a series of interview questions about the gameplay experience.

Table 1: A table of the reported demographics of our sample

	Male	**Female**	**White**	**Black or African American**	**Asian or Pacific Islander**	**Hispanic, Latino, or Spanish Origin**	**Not Reported**
Number of Players Reported	18	13	10	9	5	3	4

We are following Fullterton's (2014) approach to playtesting, which calls for consistent, iterative, play-centric testing across the development cycle of a game. Thus, the data that we present in this paper comes from multiple evolving versions of the game, as well as targeted playtesting data for specific puzzles. The methods employed across these iterative sessions included cooperative inquiry, think aloud protocols, and traditional playtesting. Data was analysed using an open, interpretive grounded theory method (Charmaz, 2014). Authors 1 and 3

engaged in consensus coding (Charmaz, 2014; Stemler, 2019) through consistent debriefing, memoing, and coding across several rounds of playtesting. Consensus was reached through the two coders through an iterative process of collecting data, reviewing it line by line, and discussing emerging themes throughout the analytic process (Cascio, Lee & Vaudrin, 2019; Stemler, 2019). Through this iterative method of analysis, we reached theoretical saturation for this stage of the game design process (Star, 2007). The central themes that emerged through the analysis serve as the headings for our findings section below.

4. Preliminary Findings

Our findings emerged around three themes that corresponded to the design of our game: (1) how players responded to the **narrative** of the game; (2) how players responded to **the cybersecurity and computational thinking concepts** contained in our puzzles; and (3) how they experienced these elements combined through gameplay that focuses on **exploring an interactive world**. The bolded themes above evolved from a higher level codebook that focused on:

- multiple 'hooks' present in the game, meaning designed elements meant to attract a broad range of players – these were the primary kidnapping plotline, the ecological storyline, cybersecurity and computational thinking, and helping characters and NPCs to solve problems;
- puzzle solving behaviour from players, meaning player verbal and non-verbal responses to the challenges in the game (see Figure 1), as well as player responses in interviews to questions about strategies and conceptions of the in-game puzzles;
- player engagement with non-puzzle mechanics which serve to tie the game experience together, for example the interactive narrative elements, and the game-world and level design;

From across these broad initial codes, we narrowed our codebook into the subject headings which serve as our findings, and are presented below.

4.1 The Importance of Multiple Narrative Hooks

Overall, players reacted positively to the presence of multiple narrative hooks. An example of this comes from Kevin (Male, 14, White), who responded to an interactive storytelling element early in the game, which takes the form of a cork-board that tracks the actions of the mysterious HEX corporation, saying, "*HEX is behind her disappearance? What the heck is HEX?*" Later in his interview while sharing about his views about the narrative, he said, *"I have a feeling it'll go into more about the corporation thing, the HEXCorp, but it could also easily go into like what crashed the ship … I'm probably going to have to break into some kind of HEX Corp headquarters or something like that.*" This matches to our larger goal to use HEX-related elements to bring more cybersecurity elements into the narrative by having players follow a narrative path that asks them to both attack and secure networked systems in pursuit of rescuing the kidnapped crew from HEX. Similarly, the ecological storyline serves as a hook for other players. One example comes from Darren (Male, 12, African American) who responded to a small environmental puzzle where players must find sea turtles aboard the starting boat area, saying, "*In the introduction, like before the game, it explained that you're on this boat trip with these other people – other students and professionals – and you can interact with the things, and even though you don't need to learn what each person does it is cool to know that. Then you have to help find the turtles, and it's cool because they're all around the place.*" In addition to the thematic elements of the narrative, we have also been using a guiding design consideration to have the player help other NPC and also save the ecosystem of the island. Casandra (Female, 13, unknown) responded extremely positively to the game, and when asked about the purpose of the game says that it's about "*be[ing] friends with people, and helping them out.*" Steven (Male, 13, African American) said that an enjoyable aspect of the game was that "*even though some bad things may happen, we can still fix it."* Having multiple threads appealing to different aesthetic and narrative approaches allows us to 'hook' players with differing interests and guide them towards cybersecurity aspects of the game.

4.2 Balancing Scaffolding and Discovery

Across the five puzzles currently in the game, we have gathered data revealing how to convey the complex ideas that underly cybersecurity in a way that both supports novice learning while also providing the thrill of discovery. An example of this was identified in early iterations of the wire puzzle, where we observed players not understanding the logical rules that underpin the puzzle's gameplay, which were initially contained entirely in a text-box on the side of the screen (see Fig 2.b). This was clear in Alex's (Male, 12, African American) playtesting data when he read the entire set of instructions, stumbling when he got to the final rule, "*Same color wires cannot be in neighbouring ports.*" After reading this, he sighed, and said, *"Oooook… I kinda' don't understand.*"

As he continued, he became more visibly frustrated. While the previous puzzles had offered a layered series of clues situated within the narrative (e.g., the players find a cipher and connect this to a visual hint of the key on the wall, along with hints from the NPC friend characters), the wire puzzle instead relied entirely upon the player's ability to read and interpret the written rules. After over 4 minutes of struggling with this puzzle (gameplay up to this point had taken approximately 10 minutes), Alex begins to understand the rule about wires not being able to be placed in matching ports. He ultimately succeeded in figuring out the correct configuration, and said, "*Ok then. It doesn't want me to put those wires together. [sarcastically] What beautiful logic*." Although Alex enjoyed the game overall, this interaction pointed us towards an important design change, and led us to embed the wire puzzle rules into collectible items in the game-world, along with modifications to the language of the hints. Through subsequent testing we found that players became stuck on this puzzle less often, indicating the success of this approach.

4.3 The Tricky Balance of Exploration

Our participants have had a wide array of prior gaming experience resulting in varying success in our use of exploration as a game mechanic. A frequent design tension has been finding the right balance between allowing players to explore and directing them productively through levels. An example can be seen with Nicolas (Male, 12, Hispanic, Latino, or Spanish Origin), who enjoyed the first relatively linear part of the game, but, as gameplay becomes more open, Nicolas became frustrated and not sure what to do next, saying "*Oh my god… what am I supposed to do!*" Nicolas eventually asked for facilitator help in navigating this portion of the level. In his interview, Nicolas expressed engagement with the puzzles, but said that exploring the level was the most frustrating aspect of his experience. Nicolas also mentioned that he plays games infrequently, and most commonly multi-player sports games. More experienced players found this aspect of exploration to be enjoyable, like John (Male, 14, White), who upon seeing the more open beach level remarked, "*This way does not seem like the right way. Where in the world do I need to go? Well, I guess it's less straightforward now. So that's nice*." Consistently across our data, players with less prior gaming experience had difficulty with exploration, however as discussed below, exploration is still a priority for the design of our game.

5. Discussion, Limitations, Next Steps, and Conclusions

5.1 Discussion

Through our iterative design and testing process, we identify three design conclusions.

1. **Multiple narrative hooks are a productive way to introduce players to a complex domain like cybersecurity.** Considering our demographic and the desire to provide multiple pathways into cybersecurity, this is a very positive finding, and helps to inform our approach going forward. We present this as a design consideration for other designers seeking to broaden participation in any field.
2. **By situating puzzles in rich, explorable worlds, designers can ease players into a domain that is necessarily complex and multi-layered.** We can see this clearly in Alex's example, and as this was an early finding through our playtesting process, it has also been a valuable guiding design consideration in our process.

Given the above, this also requires us to (3) create a gameplay experience that incorporates exploration as a core gameplay mechanic. While some players reacted positively to this design, other players respond negatively to exploration. This is a tricky problem to solve, and one that we are still actively working on and see as a productive avenue for further research.

5.2 Limitations and Conclusions

Our goal for this work is to introduce cybersecurity to youth through narrative and puzzle mechanics. As we are still in the design phase, we cannot yet make claims about affective or learning outcomes but we do see players being drawn gradually to cybersecurity through the game. This also represents small-scale qualitative playtesting, which is reasonable given where we are in the design process. It also limits the generalizability of the claims reported here. Moving forward, we plan to roll the game out to a wider audience and will evaluate player behaviors at scale while also expanding the game narrative and further developing and deploying the game design principles outlined in this work. A second ongoing strand of research is to understand player reactions across demographics. Although this showed itself to some degree in our current data analysis, this is a dimension of our data we wish to understand more completely as our analytic work progresses.

As with any game development process, our game has limitations due to the structure of our team. We recognize that cooperative inquiry (e.g. Druin, 1999) could be productively used to understand player reactions to cybersecurity content, and we did use cooperative inquiry for initial ideation during the game development process. Further usage of cooperative inquiry to design challenges, narratives, and mechanics is work that we would like to pursue in the future, but for the work presented above we have limited our testing efforts to think-aloud protocols and traditional playtesting methods.

Altogether we find that game-based learning represents a rich educational context to introduce underrepresented learners to the domain of cybersecurity. We have described several affordances of game-based learning that we have leveraged in the design of *HEX*, and we offer these preliminary findings to other designers seeking to create similar games.

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Fighting against Fake News Using the Card Game "Follow Me”

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Abstract: The increasing presence of fake news in the media, especially on social media poses significant damage to our society. Disinformation undermines the credibility of conventional media and the authority of government officials, contributing to the destabilization of democratic systems. The coronavirus pandemic has accelerated these processes; people have been forced to function intensively in the online space, with a related increase in the time spent on social networking sites. At the same time, the so-called infodemic has been unleashed. The amount of fake news – especially dubious information related to the coronavirus – has increased significantly. The most effective protection against fake news is continuous education and the development of critical thinking. Traditional educational approaches are not always sufficient and fail to adapt quickly enough to the dynamic development of technology and society. Educational games can effectively reach young audiences, and therefore they are coming to the fore. These educational games include the card game Follow Me, which focuses on introducing the dynamics of social media. The target audience of the game is primarily secondary school students, and it has been developed with an emphasis on effective use within the high school educational process. In the game, players take on the role of social media users in order to gain as many followers as possible, while trying to maintain their credibility and detect fake news published by other players. The game features articles covering four different domains (health, science, geopolitics, and society), and due to this diversity, topics from different domains inevitably emerge during gameplay. The game was published by the Slovak game development studio Impact Games and is currently available in print in Slovak language, with English, Croatian and Slovenian translations already available online. The aim of this paper is to introduce the game Follow Me and analyse its game mechanics, mainly focusing on the educational elements. The main contribution of the study is a deeper understanding of game mechanics that can develop critical thinking and an estimation of their effectiveness in educating players about the safe use of social media.

Keywords: critical thinking, educational games, fake news, infodemic, social media

1. Introduction

Fake news can be understood as a set of reports about events of public interest that attempt to mimic reliable sources while containing false or misleading information (Levy & Ross, 2021). Such news can be encountered in different domains: news dealing with political events, information about the COVID-19 virus and other health care topics, or fake studies on social issues. The increasing amount and rapid spread of fake news pose an increasing risk to individuals but also to society (Lazer et al., 2018) and is often used to (politically) polarize society and to influence public opinion through false and misleading information, leading to a loss of trust in authorities, experts, and the government (Zhang & Ghorbani, 2020).

The rapid development of technology, especially the easy access to the Internet with almost unlimited possibilities to consume, to create and to share information on different platforms, contributes significantly to the spread of fake news (Simko et al., 2021). Another factor is the COVID-19 pandemic, which has forced a large part of the population to operate largely in the online space. In general, people are not aware of the threat of fake news and are therefore more easily manipulated and prone to believe the information they receive in the online space (van der Linden et al., 2020). The World Health Organisation (WHO) has also warned that, in parallel with the coronavirus pandemic, we face a so-called infodemic, which they characterized on their official website as "too much information including false or misleading information in digital and physical environments during a disease outbreak. It causes confusion and risk-taking behaviours that can harm health".

One of the existing approaches to dealing with fake news is fact-checking, i.e., verifying and marking (especially online) information, sources, and articles as true or false. Content flagging is done either by human experts or, more recently and increasingly, by machine learning methods (Chung & Kim, 2021). The downside of this approach is that it often achieves the opposite effect; blocked messages come to the fore and reinforce the credibility of conspiracy theories claiming that the government or clandestine organizations are trying to hide some information or rule the world. Another risk is the potential for error; mislabelling a fake report as true can increase the impact of that report and mislabelling a true report as false can significantly reduce the credibility of fact-checking methods.

The most appropriate solution to counter the impact of fake news is clearly to educate people so that they are able and motivated to autonomously evaluate and verify the credibility of sources, articles, and information. However, this requires a long-term and well-planned process, a change in the education system and additional training for teachers, the results of which will only become apparent over several years. Another educational challenge is to reach the older generation, who often no longer have the time or motivation to learn and have developed opinions and attitudes that they do not want to reconsider. At the same time, fake news is constantly evolving, and fraudsters are trying new and new ways to convince people, so it would be necessary to create an education system that is flexible enough to face these challenges. Therefore, modern educational elements are being experimented with. This includes educational videos, podcasts and educational board games or digital games. These tools can effectively reach out to the younger generation and provide learning in an engaging way.

The aim of this paper is to identify the game mechanics offered by the card game Follow Me, developed by the Slovak game studio Impact Games. In particular, we conduct qualitative content analysis, focusing on the educational potential of individual game mechanics in the context of fake news recognition. Therefore, we can formulate the following research questions:

- RQ 1: What game mechanics does Follow Me work with and what is their educational potential?
- RQ 2: What is the benefit of debriefing after playing Follow Me?

2. Theoretical Background

2.1 Game-based Learning

Game-based learning (GBL) is gaining more and more attention among both researchers and in practice (Anastasiadis et al., 2018). GBL can be defined as an environment where new knowledge and skills can be acquired through game mechanics (Deubel, 2006). The fundamental idea is to educate players through repetition, failure, and accomplishing goals (Hanghøj, 2013). Although many studies point out the potential of games in education, the strength of evidence is not always sufficient to determine how games can impact 21st century education (Qian & Clark, 2016).

The role of the teacher is crucial in BGL. They must be familiar with the game mechanics used and understand their purpose, while managing the activity appropriately to fulfil the educational potential of the game (Hanghøj, 2013). In addition, the teacher must be able to dynamically change their role between four personas: instructor, playmaker, guide, and evaluator (Hanghøj & Brund, 2009). As an instructor, they plan and explain the goals of the game; as a playmaker, they explain the rules, dynamics, and goals of the game to the players; as a guide, they guide the players to achieve the goals of the game and answer questions during play; as an evaluator, they evaluate the game, give feedback to the players, and ask evaluative/reflective questions.

Incorporating games into the learning process brings benefits for both educators and students (Plass et al., 2015). First, by using games, it is possible to increase students' motivation and arouse their interest in the topics addressed in class. In doing so, relationships are built between the players and the teacher thanks to their mutual interactions during the gameplay. At the same time, properly designed games can relieve the work of the teacher, as part of the educational process is transferred to the students' interaction with the game.

In the case of board games, we can also talk about another advantage that is directly associated with the nature of the game, which is to gain experience and build social relationships through communication while playing. This aspect is particularly important when we consider that children almost all over the world have been forced by the pandemic to operate exclusively in the online space for long periods of time. Thus, their relationships within the classroom have grown considerably weaker.

2.2 Developing Critical Thinking through GBL

Critical thinking has had several definitions over the past decades (Huitt, 1998), but all interested scholars agree that this ability is closely related to the processing and recognition of false and true information. For this reason, the development of critical thinking skills is crucial in fighting fake news. In doing so, in addition to the critical thinking skill itself, it is also important to build the habit of using this skill in everyday life (Blake et al., 2002).

One approach actively used in GBL aimed at developing critical thinking skills includes the inoculation theory (Roozenbeek & van der Linden, 2018). This theory is based on the biological metaphor of inoculation: an organism is exposed to bacteria or viruses in safe amounts so that later, when encountering a real disease, it

knows how to respond in an effective manner. This works similarly in games where players can be exposed to the threat of fake news in a safe environment so that they can later recognize it in real life.

There are several games that focus on fighting fake news. These include the card game The Fake News Game (Roozenbeek & van der Linden, 2019). The game is designed for larger groups of players, which are divided into teams of two to four players. Each team is assigned a role according to common types of disinformation spreaders: denier, alarmist, clickbait monger or conspiracy theorist. Each team's goal is to use the available text cards to compose an article on a given topic that most closely matches the assigned role. Another game by the same authors is the digital game Bad News (Roozenbeek & van der Linden, 2019); in this case it is a single-player online game where the player is, again, situated into the role of a disinformation spreader and gradually learns about the most used techniques employed in writing and spreading fake news and is also introduced to the possible motivations of these people. Another game that tackles this topic, although differently, is The Fake News Detective (Junior, 2020), which, unlike the previous games, puts the player in the role of a professional fact-checker and tries to teach them the methods through which false information can be detected.

Experiments conducted with these and other games suggest that games can be a powerful tool for developing critical thinking skills and thus combating fake news (Basol et al., 2020; Roozenbeek & van der Linden, 2019, 2020).

3. Follow Me and Its Educational Potential

Follow Me is a card game developed by the Slovak game development studio Impact Games. The game focuses on the development of critical thinking and digital literacy. Players are put in the role of users of a fictional social networking site Duckface, where they try to gain as many Followers as possible. The primary target audience is high school students, but the game can also be enlightening for older generations. The game teaches about the functioning of social media, how to distinguish between fake and true news, how fact-checking works and about responsible online behaviour.

The game can be played by two to four players at a time; for a larger group of players (such as a classroom), it is recommended to divide the entire group into smaller teams, and provide each team with its own game set. Players compete while playing but are also given tasks that they must solve together. In principle, one game can last as long as all the cards are not spent. The recommended playing time is approximately thirty to forty-five minutes (eight rounds for four players and nine rounds for three players).

In this chapter, we describe the game mechanics in more detail and examine how they reflect the real world and how they educate players. The game has not yet been tested on a larger sample of players; this work focuses on a qualitative analysis of the game mechanics. Quantitative testing of the game is a challenge for further research.

3.1 Basic Game Mechanics

The game contains 4 types of cards, each distinguished by colours and icons: News, Followers, Action Cards, and Events.

The News cards (Figure 1) contain various articles that players can share to gain new Followers. News topics are divided into four categories: health, science, society, and geopolitics. Each News card belongs to one or two categories and is either a fact or a hoax. Each fact has a legitimate website, a specific author name listed, and an informative style of writing. On the other hand, hoaxes involve at least one of the following traits: the author is not mentioned, or a nickname or random string of characters is used, the website does not look legitimate or the text of the article is expressive and contains errors. Noticing these signs should be the primary step in judging the veracity of articles, even in the real world. This information is not communicated to players in advance; they are expected to learn it while playing or are introduced to it during debriefing.

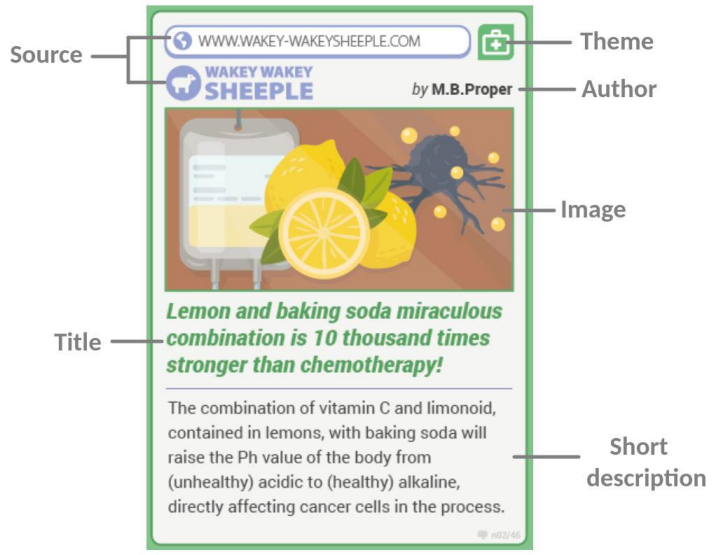


Figure 1: Sample News Card. Each News card contains several pieces of information that can help to determine the credibility of the news (source: Impact Games, Follow Me methodology guide)

Another type of card is the Follower card (Figure 2). These are the most important cards in the game, as the player with the most Followers wins. The Follower follows the player who has shared the most articles on topics of interest to them, while also requiring a certain level of credibility, which players gain by creating their own original content or debunking hoaxes shared by other players. Again, the Follower mechanic simulates the real world: by sharing a large amount of news on various topics without regard to its accuracy, a player can quickly gain followers, but if other players reveal that they have shared hoaxes, they lose credibility and will not gain any more Followers in the long run.

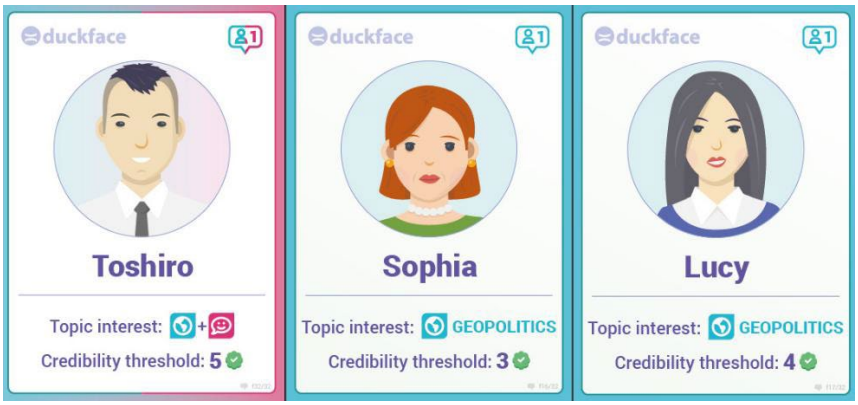


Figure 2: Examples of Followers' cards. (source: Impact Games, Follow Me methodology guide)

The third type of cards are Action cards. These represent actions that players can perform, and players keep them secret. There are several types of these, which affect the game in different ways. One of the most important is the Original Content card, which represents writing one's own article based on verified sources on a specific topic. Sharing original content increases player's credibility and subsequently works like other shared news. This card serves to make players aware that sharing articles per se is not bad and can even be beneficial; the problem lies in sharing fake news.

Another important action card is the Fact Check card. This card is used to verify articles shared by other players. If a player debunks a hoax, they gain credibility tokens and the player who shared the hoax loses credibility. Verification of news is done using the attached Fact Checker's Guide, which contains information about the veracity of the articles, including an explanation and a link to sources where players can verify the information. This card teaches players how to fact-check real news: first they must be suspicious and disbelieve any news, then they can turn to fact-checking tools and portals where they can verify the information by comparing it with reliable sources.

The last type of cards are Event cards. At the end of each round, one Event card is turned over. Each Event brings a new effect to the game, which the players must evaluate together. These effects are educational (e.g., a press release appears, stating that any News whose author is just a random string of characters is an artificial intelligence-generated hoax), but they also affect the game itself (e.g., players who have shared artificial intelligence-generated News lose credibility). The aim of these cards is to encourage communication among players through cooperation during the evaluation of an Event, while developing their critical thinking and digital literacy.

3.2 The Game Loop

Before the game starts, each type of card is shuffled in its own deck; each player receives four credibility tokens and two Action cards (Figure 3). The game is divided into rounds. During each round the active (i.e., starting) player is someone else; the active player's token moves in the direction of the game each round. Each round consists of eight phases.

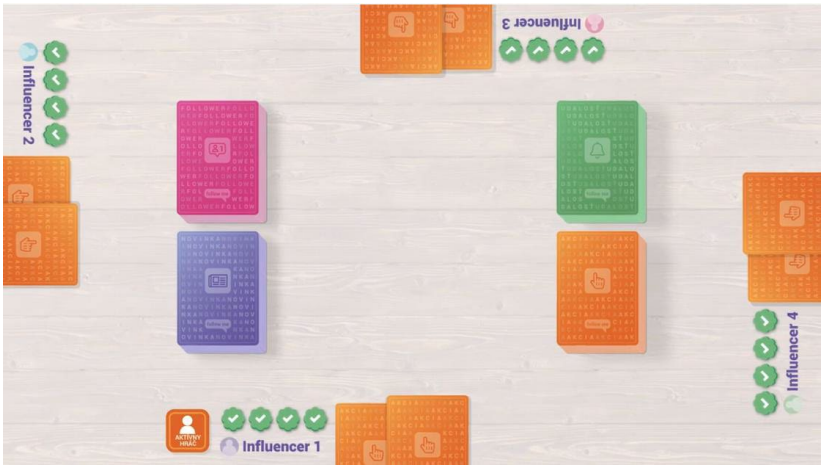


Figure 3: Game layout before the start of the first round (source: Impact Games, Follow Me methodology guide)

3.2.1 Action Card Draw

At the beginning of each round, starting with the active player, each player draws a card from the Action card deck.

3.2.2 Playing Action Cards

During this phase (again, starting with the active player), each player may play as many Action cards as they wish, except for Original Content, which may be played just once. The effects of the cards are immediately evaluated. Depending on the type of card, the player places the played cards in front of them or in the discard pile. If a player does not want to play any more cards, the next player follows until all players have had a chance to play cards.

3.2.3 Revealing News Cards

In this phase, as many novelty cards are revealed as there are players, and each player can take a close look at them.

3.2.4 Sharing News Cards

In this phase, each player in turn can choose one News card from the turned over News cards and place it in front of them. The unused cards remain face up, and in the next round, again, as many novelty cards as there are players will be added to them. This will potentially give players an increasing number of novelty cards to choose from.

3.2.5 Revealing Follower Cards

As with the News cards, as many Follower cards are revealed each round as there are players.

3.2.6 Acquiring Followers

In this step, the players divide the Followers together (i.e., the order of players no longer matters). The Follower will follow the player who currently shares the most news in their topic of interest and meets their credibility level requirements. If multiple players have the same number of articles on a topic, the higher credibility level will function as the tiebreaker. If they also have the same credibility level, the Follower will remain placed in the middle until the next round, at which point players will be able to acquire them again. This implies that there may be quite a few unclaimed Follower cards left in the middle of the table, especially at the beginning of the game. Follower cards remain with the player (although it is possible that they may not meet their requirements later in the game), they can only be removed using Action cards and Event cards.

3.2.7 Revealing and Resolving the Event Card

Players reveal one event card and together evaluate its effect. This serves to encourage communication and cooperation between players and reduces rivalries that may have escalated during earlier phases of the game, especially at the time of selecting News, where very different opinions on the veracity of articles may clash. It is the role of the teacher to avoid possible conflicts, even if there is a relatively small chance of their occurrence.

3.2.8 Shifting the Active Player's Token

At the end of the round, the active player's token is moved to the next player and the next round begins with the same course of actions. At the end of the game, the player with the most Followers wins.

3.3 The Role of Debriefing after the Game

The authors of the game recommend that after the game is finished, the teacher conducts a debriefing. Thanks to this, it is possible to increase the educational effect and to sort out the acquired knowledge with the students. Such a "block" of playing and debriefing can be done in free time but also during formal education, as its duration is about an hour and a half. During the debriefing it is important that there is a discussion between the teacher and the students. For example, instead of having the teacher list the characteristics of the hoaxes that were used in the game, the teacher should ask on what basis the students were deciding which News to share. During this discussion, topics such as the reasons why fake news spreads, the reasons why ordinary people share fake news, the characteristics of fake news, the role and use of fact-checking portals, and the reasons why we are prone to believe fake news can be addressed.

3.4 The Teacher's Role

The game itself will stand up well as a family board game without any guide, but it was designed primarily for usage during formal education. The role of the teacher is therefore important, though not necessary in every case. The teacher acts at the start of the game primarily in the role of playmaker, and it is important to explain the rules to everyone at the beginning and help the players to get into the game flow. During the actual gameplay, the teacher has a role of a guide, watching the players and answering any questions they may have, but otherwise should not interfere with the game or make recommendations on different strategies or on the selection of News cards. Then, during the debriefing, the teacher takes on the role of evaluator and leads the discussion with the students about their experiences with the game, this part is the most important for the teacher because this debriefing can help to further develop the knowledge gained during the game.

3.5 Pros and Cons of Follow Me

The Follow Me game introduces a number of creative elements, offering interesting educational potential in the development of critical thinking. Unlike the aforementioned games, it does not situate the players on the "bad" or "good" side; the players are ordinary Internet users. Their goal is to attract as many Followers as possible, and they can decide for themselves what strategy they will use to achieve victory. Another interesting element is the rather large amount of information that the player has to keep track of: News in front of themselves and other players, News that no one has shared yet, Followers that no one has convinced yet, the credibility of the players and the Action cards in their hand. This aspect of the game looks unnecessarily confusing at first glance, but it actually illustrates social media, where we are also exposed to a huge amount of information, quite convincingly.

The game successfully employs the inoculation theory: it allows players to experience the difficulty of judging the credibility of news and the feeling of being fooled by fake news. And while they experience the consequences of their mistakes within the game in the form of lost credibility and followers, these events, of course, have no real-world impact, bringing the players the opportunity to experiment in a safe environment. This is also why gaming should not be graded within a formal grading system in schools.

Among the disadvantages of the game are the relatively difficult rules, as there are many different actions in each round, and it can take players one or two rounds to fully understand the game. This difficulty can cause frustration and loss of interest in some types of players, so it is important for the teacher to help overcome the initial confusion to get all players into the game.

As for the disadvantages, we can also mention the limited potential for repeated playing. If players already remember which articles are true and which are false, the game loses its purpose and entertaining nature. There are currently forty-six news cards in the game, of which players will use approximately thirty-two to thirty-six (depending on the number of players and rounds) in a single play, with only some verified by Action cards fact-check. When debriefing is considered, there is a high chance that after the first game players will learn to recognize the hoaxes in the game with a fairly high probability. On the other hand, this means that the game has fulfilled its purpose and playing it again is not even necessary. It should also be noted that within a few months the game can be played again without any problems, because by that time most of the news will be forgotten by the players.

4. Conclusion

Fake news poses an ever-increasing threat to both individuals and society as a whole. The rapid development of technology and social media is also contributing to the rise of fake news. People are generally unaware of the dangers of consuming distorted information, which makes them easy to manipulate. The situation is further worsened by the coronavirus pandemic, which, in addition to forcing people to move across the online space, has also triggered a new wave of (primarily medical) fake news called infodemic. One of the efficient tools to combat the impact of fake news is to label news as true or false through fact-checking. However, this approach does not appear to be entirely sufficient, and similar efforts need to be focused on educating people and developing their critical thinking skills. In this process (especially when working with younger generations), modern tools such as podcasts, videos and educational games can be very useful.

In this paper, we discussed the educational card game Follow Me. This game focuses on social media simulation and puts players in the role of Influencers trying to get as many Followers as possible. They achieve this goal by creating their own content and sharing articles on different topics, while they have to be careful about their credibility and not share hoaxes. The game can be played by two to four players and a single game lasts approximately half an hour to forty-five minutes. Follow Me successfully uses the inoculation theory and offers players a safe environment to learn about the phenomenon of fake news. In addition, it educates players in an entertaining manner about the typical features of hoaxes, the process of fact-checking and the dynamics of social networking sites. An organic part of the educational process is the post-game debriefing, which provides a space to discuss the topic in order to deepen and consolidate the knowledge gained during the game. This activity requires adequate preparation by the teacher but is supported by the methodological guide provided by the authors of the game, which is freely available on the Internet.

One of the biggest challenges of the game is its localization, as it is only available in print in Slovak language, which is why it cannot be used internationally yet (although online preprint versions are freely available in English, Croatian and Slovenian language). The most challenging task related to using this game in teaching is to explain the rules to the players and help them navigate the game's rather complex environment without suggestively hinting at possible strategies. Among the drawbacks we can also rank the replayability, which is limited by the number of News cards: when players memorize them, the game loses its purpose. This problem can be solved by releasing additional News cards, or by creating a custom set of cards (the authors offer a publicly available blank News card format).

Future work needs to focus on validating the assumptions about the educational power of Follow Me, primarily through experiments, in a similar way to what was done for the other games mentioned above: first measuring the ability to recognize fake news before playing, then playing the game and going through debriefing, and finally measuring the ability to recognize fake news again at the end of the experiment. The data obtained from such experiments can offer a more detailed insight into the potential of the game, showing its strengths and weaknesses, as well as providing experience with the possibilities of using it in practice.

Acknowledgement

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Unlock Financial Knowledge in Managers Through Games

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Abstract Financial literacy for managers and owners of Micro, Small and Medium Enterprises (MSMEs) is defined as the combination of awareness, knowledge, skills, attitudes, and behaviours that a potential entrepreneur or business owner should have to make effective financial decisions to start a business, run a business, and ensure its sustainability and growth (OECD, 2020). To ensure this combination of financial knowledge and skills, different educational perspectives may emerge as the solution. The use of gamification and digital game-based learning (DGBL) are educational methodologies largely used in formal and informal environments, for different target audiences and different fields of knowledge, including finance. However, it is largely used by children and younger people in the same contexts described above. We find a gap that justifies further research on the formal use of DGBL in the adult population, namely for the development of financial literacy. For the use of gamification in this context to be effective is essential to identify which knowledge, skills and attitudes are required for MSMEs managers. The OECD (2020) questionnaire is an example of an instrument used to measure adult financial knowledge namely in managers, owners and future entrepreneurs of MSMEs. The financial literacy content for managers includes questions on basic concepts of asset management, inflation, investments, cash flows and risk analysis. However, at the top of our knowledge, we find little research to support how can we actively develop this awareness and knowledge through games. In this study, through exploratory analysis of government documents and literature, we sought to understand the three scales for measuring financial literacy, namely, financial knowledge, financial attitudes, and financial behaviour, which are the main contents that should be included in the pre-game's assessment and on the learning objectives. The second concern is how to include these scales in the game to positively impact the behaviour, attitudes and knowledge of the managers of MSMEs. Thus, the contribution of the study is to create through the metrics used to measure financial literacy and the game mechanisms used a proposal for a model for designing digital games for financial literacy. Policymakers, private associations connected to MSMEs, and other players may take, for sure, lessons to be learned to prepare better the managers to guarantee stable and sustainable enterprise support.

Keywords: Digital game-based learning; Gamification; Serious games; Managers; Financial literacy; Entrepreneurship skills

1. Introduction

The low level of financial literacy among the population is a global issue and needs further attention, also in developed countries such as Portugal (OECD, 2016). Evidence suggests that individuals with better financial education will make better investment and savings decisions during their lifetime. And will improve their financial well-being in subjective and objective terms (Klapper and Lusardi, 2020). Lack of financial education among individuals has serious implications not only for the decisions people make for themselves but also for society. Therefore, the stakeholders involved will need to continue to identify new alternatives and strategies to disseminate knowledge in a sustainable way to the general population (Oliver-Márquez, Guarnido-Rueda and Amate-Fortes, 2020). In this study, our focus study was on the adult population, more specifically owners and managers of micro, small and medium-sized enterprises (MSMEs). The complexity of finance and access to financial markets is one of the main challenges confronting an entrepreneur (Kumar *et al.*, 2022). Considering that MSMEs represent the majority of enterprises in the world and are responsible for much of the growth and development of countries' economies, initiatives for the development of financial and entrepreneurial skills for this public need to be explored (European Central Bank, 2022).

What we usually identify in the different studies is that financial education is not linear, and there isn't one single way to implement a financial education programme for different members of the population (Urban *et al.*, 2020; Li, 2020). An effective financial education programme should effectively identify the needs of its target audience,

analyse vulnerable groups accurately, provide clear objectives and be based on rigorous evaluation metrics (Lusardi, 2019; OECD, 2020b). In this context, game-based learning (GBL), serious games and gamification are being used as an innovative approach to specific content development and transversal competencies. These methodologies encourage active learning, enhance, or introduce specific knowledge and increase users' confidence and attitude (Ikhide, Timur and Ogunmokun, 2022). While there is a significant amount of research exploring individually the importance of financial literacy in MSMEs and the use of GBL to promote innovation in education, the relationship between these two issues for the development of financial competencies in managers still has many research gaps.

In this research, the aim is to understand the relevant contents to insert in the games to improve the financial literacy development of managers, owners, and potential entrepreneurs of MSMEs. To measure financial literacy, three core competencies are used as a basis, namely financial knowledge, financial attitudes, and financial behaviour. But how do insert these scales in digital GBL to develop these competencies? To answer this question, the study initially used a critical literature review on financial literacy and its impact on MSMEs. This is followed by a review of game mechanics and how these can be applied to finance. Finally, the author sought the connection between the contents of financial literacy for managers and the use of digital games and proposed a framework with the union of these themes.

2. Financial literacy for MSMEs

Financial literacy can be described as the acquisition of the knowledge and skills necessary to manage financial services and to make more assertive lifetime decisions about saving and planning. Low levels of financial literacy are a concern for the well-being of the general population (Ye and Kulathunga, 2019; Li, 2020). According to the European Central Bank (2021), Portugal has the lowest levels of the measure of financial knowledge in the adult population of the Eurozone. The global evidence on financial literacy points to Klapper and Lusardi (2020) in the adult population shows that governments and businesses should take note of the emerging literature on these topics, as financial inclusion becomes an important part of the development policy agenda and digital financial products proliferate (Prete, 2022). Lusardi (2019), also considers that an individual's financial knowledge should be delineated as an intrinsic choice variable, similar to investment in human capital. Making this choice can allow individuals to better allocate resources throughout their lives in a world of uncertainty and constant change. Review studies on the topic, show a lack of research in the area of financial education and inclusion in the face of new digital products and the increased creation of fintech (Morgan and Trinh, 2019; Goyal and Kumar, 2021; Daud *et al.*, 2022).

For managers and owners of MSMEs, financial literacy is defined as the combination of awareness, knowledge, skills, attitudes and behaviours that a potential business, owner or entrepreneur should have to make effective financial decisions to start a business, manage a business and assure its sustainability and growth (OECD, 2020a). Different studies highlight the importance of financial knowledge, aligned to other key competences such as business knowledge and experience as essential items to ensure the sustainability of MSMEs (Eniola and Entebang, 2017; Bongomin *et al.*, 2017; Anwar, Shuangjie and Ullah, 2020). In contrast, Nikitina, T. et al. (2020), obtains positive evidence that soft skills such as motivation and perseverance are considered more important for entrepreneurs than financial and economic skills. Thus, the educational content for these managers should be different from the content for the adult population and should include basic accounting concepts, cash flow analysis, business environment analysis, risk analysis and investment management, since these topics are relevant for the financial future of organisations. All of this is aligned with the development of the transversal skills required by entrepreneurs (Ye and Kulathunga, 2019).

The OCDE research (2021), showed existing evidence on the fact that the impact of MSMEs that were severely affected by the COVID-19 crisis, differed not only in terms of sectors and size but also concerning to the financial literacy and digitalisation of these companies. Thus, many MSMEs owners have had to use their financial skills, develop new financial management strategies, and adapt their businesses to further digitalisation to confront the challenges of the pandemic. The literature evidence that the financial literacy level in MSMEs is key when it to accessing finance (Tuffour, Amoako and Amartey, 2020). Knowledgeable owners and managers can potentially reduce market failures that are driven by information asymmetries between the provider and receptor of finance (Imarhiagbe, Saridakis and Mohammed, 2017; Hussain, Salia and Karim, 2018). A positive relationship is observed in Ghana by Adomako, Danso and Ofori (2016), where access to finance and risk capital is facilitated for managers with greater financial knowledge and argumentative power and in China by Xu *et al.,*

(2020), a positive relationship between business owners with higher levels of financial literacy and access to bank loans. Moreover, financial literacy significantly moderates the relationship between firms' risk management practices and gaining competitive advantage. Managers with higher financial literacy will effectively execute risk management practices and capital market investments to gain a competitive position in the market (Kadoya, Khan and Rabbani, 2017; Songling, Ishtiaq and Anwar, 2018; Baihaqqy *et al.*, 2020). Thus, better financial analysis and reporting capabilities will enhance how MSMEs describe their financial profile to their creditors during the loan application process, improving their chances of success (European Central Bank, 2021). Cash flow analysis and projections, as well as an understanding of the basic financial situation, are essential for monitoring the agreements that are often included in loan documentation (Eniola and Entebang, 2017). Financial knowledge is also important for micro-enterprises that are tempted to lend against personal assets, such as their home or property, as collateral, without fully understanding the risks involved (Bacha and Azouzi, 2019).

2.1 Measuring financial literacy

To measure financial literacy in adults, Lusardi (2019) used questions to assess basic knowledge of four key concepts in financial decision-making: knowledge of interest rates, interest compounding, inflation and risk diversification. The results showed that only one in three participants could answer all the questions correctly. The OECD conducted extensive research and created a framework in 2016 to measure the financial literacy of the adult population and to be a reference for studies in the area (OECD/INFE, 2016). Thus, the initial framework was divided into three core competencies, namely awareness, knowledge and understanding; skills and behaviour; or confidence, motivation and attitudes. In Figure 1, the core competencies and contents that are priorities are highlighted. The remaining core competencies are then listed vertically according to their typical level of importance as agreed by the OECD/INFE experts (those competencies considered highly important are listed first).

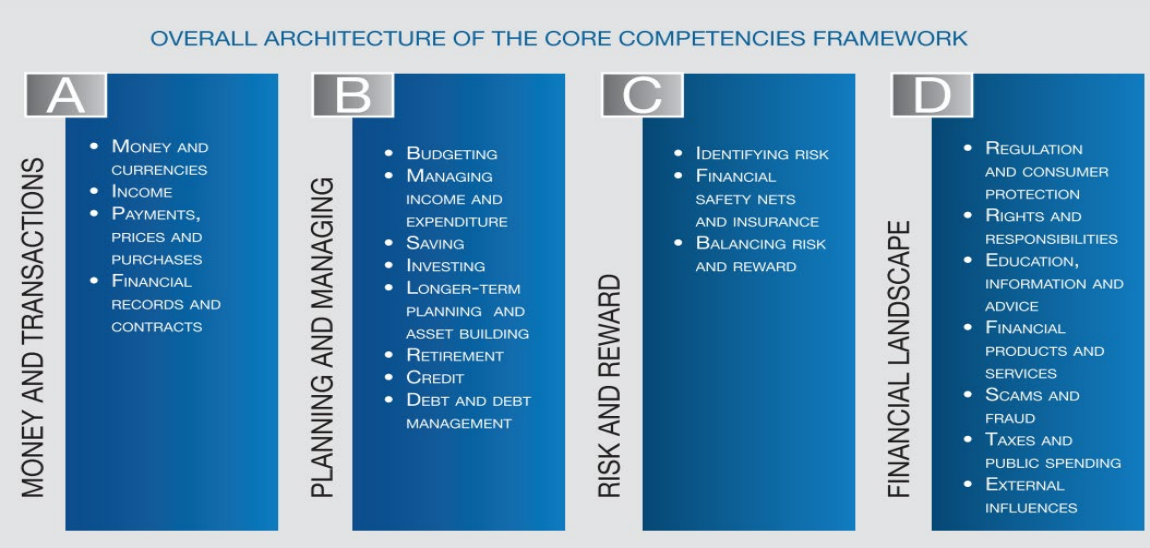


Figure 1. Overall architecture of the core competencies framework on financial literacy for adults, retrieved from OECD/INFE (2016, p. 7)

After the framework was created, the questionnaire was designed and applied to the adult population of more than 30 economies, using their levels of financial knowledge, behaviours and attitude in the years 2016 and 2020 (OECD, 2016; 2020). The main core competencies in the questionnaire are analysed as follows:

- *Awareness, knowledge and understanding*: Refers to information the individual has acquired.
- *Skills and behaviour*: It describe the competencies related to individuals' actions. It also describes the behaviours that are most likely to result in financial well-being.
- *Confidence, motivation and attitudes*: Capture the internal and psychological mechanisms that may support or impede decisions, behaviours and well-being.

Based on the adult questionnaire, the OECD identified the need to measure this knowledge specifically in owners, managers and potential entrepreneurs of MSMEs. Thus it expanded its research to this target audience and in 2018 released the *Core competencies framework on financial literacy for MSMEs* (OECD/INFE, 2018).

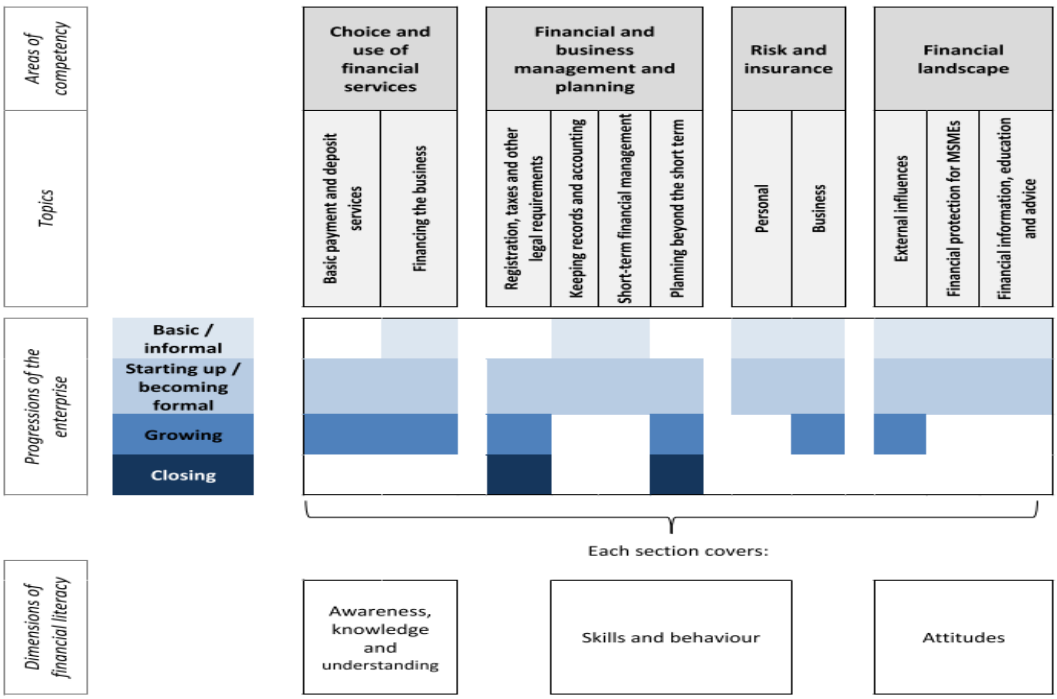


Figure 2. Overall architecture of the core competencies framework on financial literacy for MSMEs, retrieved from (OECD/INFE, 2018, p. 13)

The structure of the framework is divided in core competencies areas, dimensions of financial literacy and enterprise progressions. The core competencies areas include content on the choices and uses of financial services, financial and business management and planning, risk and insurance, and finally content on the financial landscape, which also involves external influences. The framework also considers the three dimensions of financial literacy, and the competencies are ordered along the main stages of enterprise development. This concern, with phases and content, differs largely from the content for measuring adult financial literacy. The first questionnaires were applied in the years 2018 and 2019 (OECD, 2020a).

3. Using digital games to unlock financial skills

Different methods of teaching and learning are being used in financial education programmes around the world. These new approaches to teaching are changing from a traditional approach in which the individual passively receives content, to a competency-based approach in which the individual active learning (Josef and Vera, 2017). Among these approaches, the use of GBL and gamification has been increasing in relevance in recent years, especially in schools and universities (Bayuk and Altobello, 2019; Nadolny, Nation and Fox, 2019; Hanghøj *et al.*, 2020). Tews, Michel and Noe (2017), Costin, O'Brien and Slattery (2018) and Suh *et al.* (2017), suggest that organisations should consider the use of gamification as a viable strategy to promote informal learning in addition to traditional learning supports, which reinforces the idea that financial literacy in MSMEs managers can be developed through games.

The concepts of GBL, gamification, serious games and educational games can be ambiguous and often get confused. Serious games are part of the GBL methodology and provide employees with a relevant storyline for the development of technical and transversal competencies (Nadolny, Nation and Fox, 2019). The gamification uses storylines and achievable goals, feedback on progress and rewards such as achievement badges and recognition. These methodologies implanted in the business context also offer employees opportunities to fail, learn from their mistakes and try again in a safe environment (Bayuk and Altobello,2019).

Organisations are finding that applying a GBL and gamification approach to corporate training is helping them to increase employee engagement and drive performance beyond traditional training approaches. However, poor game design is a major shortcoming of many "gamified" applications. For this reason, games need to be analysed according to the specific learning objectives you wish to develop (Bitrián, Buil and Catalán, 2021).

Learnovate Centre (2012), evidence the use of some serious games used in the corporate environment in the financial services sector. For example, *€conomy* is a serious game based on the monetary policies of the European Central Bank to teach employees about the impact of interest rate changes on unemployment, output growth, inflation, and other vital economic indicators. Another initiative *BankersLab* provides a suite of 'gamified' training products for the retail banking industry that includes *CollectionLab,* a serious game designed to train employees. Another example is *True Office*, this game allows employees to explore scenarios through interaction, gameplay and immersion. The analytics dashboard allows management to globally analyse employee performance and provide early intervention and support. And playfully *CoCo Sim*, is a game based on fictional chocolate in New York, where the player must manage cash flow and stock levels to achieve a high level of satisfaction while remaining profitable. The game integrates modules on the business process, problem-solving and basic accounting.

In the academic literature, there is not much evidence of serious digital games applied to organizations in the field of finance. Rodrigues, Costa e Oliveira (2017), use gamification to motivate customers to use e-banking and improve their financial literacy. The study provides guidelines for the design, development and content of e-banking for stakeholders. Hoffmann and Matysiak (2019), developed *InvestNuts* to motivate the youth population in Germany to invest in stocks. The results of the prototype showed promise.

Designing serious games, as opposed to casual games, involves applying best practice guidelines to provide challenge, curiosity, control and fantasy to participants (Learnovate Centre, 2012). We analyse below, each of these elements and modes of use in game design.

Control: The feeling of control is an important motivator in gaming. Thus, for a game to be successful must elicit a sense of the power of choice and personal control in the player. This will generate motivation and engagement. Concrete challenges using timers, clues, and level scores are usually used, presented for the involvement of the target user. Limited amount of time to complete an objective (Suh et al.,2017).

Challenge: The game should have clear and fixed goals that are relevant and achievable by the player. The narrative must provide context and meaning for learning. Challenge will encourage participants to embrace difficult tasks through obstacle courses or trials. To increase financial literacy the content should use the decision-making and or problem-solving skills of the participants (Hanghøj et al., 2020).

Flow: To maintain flow the challenges must be appropriate to the target audience. There should be a balance between frustration (games that are too hard) and boredom (too easy). In this case, it is advisable to use skill levels proportional to the level of difficulty. To challenge the learner to a point where they could still succeed in the game (Devraj, Colyott and Cain, 2021). For example, within the financial content, the content can be organised hierarchically in order of increasing difficulty, with the end point of a sector being a cumulative test or quiz on content from previous levels.

Feedback: Players must receive this feedback as the game progresses. All types of feedback should be unambiguous and immediate. Supportive or guiding feedback should guide and prompt the player into the correct action, rather than explicitly telling them what to do (Nadolny, Nation and Fox, 2019).

Curiosity: These can be sensory or cognitive. Cognitive curiosity refers to some element unexpected by the player, which forces them to reflect and identify the information to solve the problem. Sensory curiosity, on the opposite, can be aroused through audios and visual effects, as long as these are relevant to the game and not superfluous. Sensory-based cues or game aspects add to the degree of immersion in the experience (Bayuk and Altobello, 2019).

Fantasy: Fantasy contributes to the player's intrinsic motivation. This aspect should match the narrative and the intended learning objectives. For example, the system exposes players to various points of view and sounds. Players can take on the role of an avatar that may differ from themselves in real life (Nadolny, Nation and Fox, 2019)

In order to insert these elements in a digital game, a widely used framework is based on mechanics, dynamics and aesthetics (MDA). The MDA explains the games by this structure, in which mechanics refers to the design of a system or control mechanisms responsible for creating the dynamics and elements within the context of the game, such as rules or content that provide the structure. Dynamics, on the other hand, are the interactions between users and the system, which include the actual conditions of the game, such as the definition of how participants will interact or how they will receive feedback within the game. Aesthetics corresponds to the user's

emotional response to the game, that is, it will create in the user the feelings or emotions desired through gameplay, such as fun or curiosity (Barber, Petter and Barber, 2021).

Based on the game-based design diagram proposed by Barber, Petter and Barber (2021), we have developed our framework, with the key mechanics, dynamics and aesthetics that are most suitable for teaching financial content to managers, owners and potential entrepreneurs (see Figure 3).

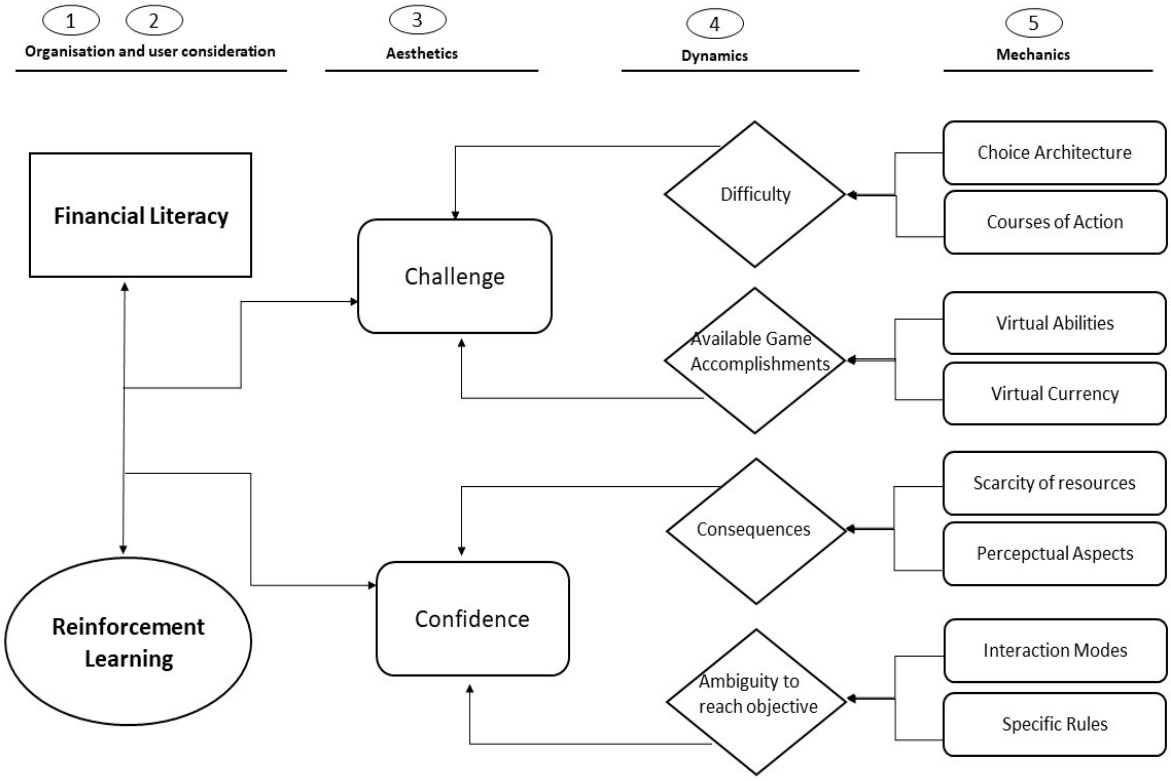


Figure 3: Framework for game design in financial literacy. Adapted from (Barber, Petter and Barber, 2021)

These are some important elements to consider when creating and organising the structure of the mechanics and design of games with learning objectives. For the creation of the framework, steps 1 and 2 comprise organisation and usage considerations. In our scenario, the problem will be *financial literacy* and the objective is the *development of content learning for training purposes*. Next, in step 3, it is necessary to understand the elements that support the aesthetic and identify which aesthetic most appropriately supports both the defined problem and the purpose of use. In our example, we chose *challenge* and *confidence* to promote intrinsic and extrinsic motivation of game participants. The main purpose of these elements is to encourage players to embrace difficult tasks to bring enjoyment, through obstacle courses or trials and to enable an individual to improve their belief in their abilities or skills.

After choosing the aesthetic, complementary dynamics need to be selected to support the desired aesthetic. Using dynamic game-based elements will identify how users will interact with the system and how the system will respond to the users' actions. The dynamics chosen in step 4, according to the elements identified by Barber, Petter and Barber (2021), that are aligned with the *challenge* and will be important for our objective, is to increase the *difficulty* over time, through phases for example, to encourage motivation and flow. We also point the *available game accomplishments*, which correspond to different forms of achievements that can be obtained in a game. These elements correspond to scores, levels of learning, finding items and completing quizzes. For the aesthetic element of confidence, we listed *consequence*s and *ambiguity to reach objectives*. *Consequences* are actions (good or bad) that will occur in the game, depending on the players' decision. The *ambiguity to reach objectives* can be achieved through puzzles, mysteries, riddles, clues and locks.

Finally, step 5 consists of choosing the mechanics elements for each of the dynamics elements chosen. For our purposes, we have defined some main elements that can be visualised in Figure 3. For example, *choice architecture* refers to leaderboards, badges, and progress bars. *Virtual currency* and *virtual abilities* are

currencies or abilities that can be obtained in the game, in our example we can insert cryptocurrencies. *Perceptual aspects* are used to provide immersion, such as visual and auditory elements and *specific rules* correspond to prohibited actions, penalties, or randomness introduced to create unpredictability in the game.
For the development of financial literacy for MSMEs, the content needs to be targeted at the emerging topics essential for business growth and sustainability and not necessarily for personal planning and lifelong well-being. After reviewing the specific contents for MSMEs managers and reviewing some important principles to be developed in the digital games, the authors organised in Table 1, the game design principles and possible concepts and strategies to insert in digital game design.

Table 1: Application of game design principles for the digital game in financial literacy.

Game design principles	Game application
Goal settings Clear objectives (goal setting) Reinforcement of learning (multiple opportunities to play each level) Game design to challenge and motivate (increasing difficulty in the games, each level should be challenging but achievable) User Engagement Engaging narrative For promoting extrinsic motivation Immediate feedback Increase the difficulty level Financial knowledge Financing the business Planning beyond the short term Risk and Insurance External influences Financial Attitudes Financing the business Planning beyond the short term Risk and Insurance Financial behaviour Basic payment and deposit services Financing the business Keeping records and accounting Planning beyond the short term Risk and Insurance External influences Financial protection for MSMEs Additional competencies Critical analysis Problem-solving	1. Quizzes, questions, challenges: o Binary input = True\False, Yes\No, Accept\Reject. o Multiple choice input = One or more true answer. o Number or text inputs. o Simulation interface, e.g. supply and demand dynamic interface, interest, inflation. o Pure fun: accurate clicking (shooting), timed clicking (jumping, playing instrument), fast clicking (Whack-A-Mole type). 2. Game concepts: o Key lock picking. o Combination lock opening. o Logic board: Pass power to a lamp, fan, device through AND, OR, OR gates. o Rocket payload, fuel, range puzzle. o Rotating wheel, fortune wheel (Luck). o Gears speed, torque puzzle. o Squid game-style glass bridge. o Financial risks obstacles. o Whack bad financial practices. 3. These will be mini-games in a larger game (Monopoly, Mario Party, or a new board game concept style) 4. There will be a global reward system (Stars or virtual dollars or even a crypto currency [Bonus Knowledge]) 5. Basic avatar leader board. 6. Art style: Realistic 3D or Pixel Art. 7. Web app\page, suitable technology for 2D drawing and animation. 8. Mongo DB for data storage. 9. Best software engineering practices.

The principles have been carefully thought out following the objectives set, the expected engagement and the content related to the desired financial competencies in terms of attitude, behaviour and knowledge. Transversal skills such as critical analysis and problem-solving were also listed to develop these elements in game design. For the application in the game, we consider the aspects of aesthetics, dynamics and game mechanics and list important elements in game design to be applied in this specific context. For example, we detailed the types of questions, puzzles, and challenges to insert, and how they will be inserted into the game. The type of overall reward, the characters, and the style of art to be applied.

4. Conclusion

Financial literacy is a basic and essential competence for an individual to prosper economically in society. It is increasingly important, given the rapidly evolving business and financial landscape, and considering that the digitalisation of finance, will continue to bring new opportunities and challenges for MSMEs, that research on the topic is deepened and new public policies and development programmes are created or developed in this field of knowledge.

This knowledge needs to be accessible and not the privilege of a few consumers who have greater access to education or financial advice. It, therefore, needs to be adopted in school curricula and disseminated to the context applied to businesses, to encourage entrepreneurship and for established MSMEs to grow and become sustainable over time and for managers to make better decisions regarding financial services, financial and business planning, risk and how external influences can impact their business.

In this study, it was clear that there is a large gap in the development of digital GBL within the context of financial content for MSME managers and owners. Few studies explore the topic and apply empirical studies. Most of the literature found on the topic refers to the development of games in education, for children and students. However, serious games provide an engaging opportunity for active learning in which participants are challenged and rewarded (Kadoya and Khan, 2017). Thus, whatever the barriers to adoption, the effectiveness of serious games for learning in organisations cannot be ignored. This methodology has the potential to impact learning engagement and motivation of individuals. Managers and owners of MSMEs can use this methodology as a complement to a traditional financial literacy training course or as a way to acquire important knowledge on the topic, without necessarily attending training. Serious games, have a valuable role to play in this regard and should be considered an integral part of companies' learning strategies (Learnovate Centre, 2012).

This study sought to understand the metrics used to measure financial literacy and some of the gaming mechanisms used. The study proposes a link between financial literacy and the development of serious games in MSMEs. For this, we created a framework and a model to map the game design principles to game applications in this area. As limitations, the lack of studies in the development of games for managers that are not empirically tested and published in the academic literature are pointed out and we expect to provide some impetus for future studies on the development of serious games in the area of finance and the empirical application for a larger scale of managers and owners of MSMEs, in order to measure these results and contribute to the literature on the subject.

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Finding Appropriate Serious Games in Vocational Education and Training: A Conceptual Approach

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Abstract: Stakeholders in vocational training are required to provide appropriate learning opportunities that can be used to develop the needed skills induced by technological change and thereto affected changes in the type of jobs, skill needs, activities, and other economic effects. In light of this, serious games have enormous potential, as they can simulate complex real-life situations without disrupting operations, but in a playful and motivating way, and with adaption to the individual needs of the users. This paper explores the question, how to find appropriate serious games matching the needs for a specific job and skill level. Within the research project "Serious Games for Vocational Education and Training" funded by the German Ministry for Science and Education, the Serious Games-Information Center (SG-IC, a classical web-based information system in form of a portal) and its underlying Serious Games Metadata Format (SG-MDF), as semantic basis for the description and retrieval of serious games, is enhanced according to the characteristics and needs in the field of vocational education and training (VET). Educational stakeholders can use the search engine to identify personalized game-based learning opportunities for their individual target groups. The identification of appropriate educational games is based on classifications of occupations, and skill levels on the learning side, and metadata information for the games on the gaming side (i.e. target user group, game genre, learning topics and additional keywords). The paper motivates the use of metadata and classification systems and presents the results of a literature search and overview of established classification systems of occupations, with a focus on Germany, but with correspondence to international systems. Based on that analytic work, an application profile 'vocational education and training' as an added 'variant' of the SG-MDF has been elaborated and integrated within the SG-IC as search engine for educational games for vocational training. Hereto serious games are matched with a database of occupational fields as defined by the Federal Institute for Vocational Education and Training, and main activity as defined by the microcensus, the largest annual household survey of official statistics in Germany.

Keywords: Vocational education and training, serious games, educational games, Serious Games Information Center, Serious Games Metadata Format, classification of occupations.

1. Motivation – Pedagogical discourse

Induced by the increased use of digital technologies and adapted value chains, the working world and employment is rapidly changing. It is assumed that jobs, as well as activities in almost all industries and fields of activity, will change in the future due to computerization (cf. Autor et al, 2003; Frey and Osborne, 2013; Bonin et al, 2015). Occupations with high substitution potential (cf. Dengler & Matthes, 2015, 2018, 2021; Kropp & Dengler, 2019) or jobs for which high demands are made in regard of digitalization are likely to be particularly affected. The past has shown that computers have substituted several jobs (Bessen, 2016). Due to the high share of less complex and specialized routine activities (often physical or manual) in the job, this would primarily affect workers on a low skill level and low-paid workers, but skilled workers would be also affected (cf. Dengler & Matthes, 2021; Dengler, 2016).[1] As a consequence, it can be assumed that there could be dynamic changes in occupations, skills, activities, requirements, and other economic effects. This probably could result in shifts within the employment structure, but also between or within occupational fields, industries and so on (cf. Zika et al, 2018; Weber, 2017).

Accordingly, employees will be challenged in the future to meet and master the technological changes as well as its effects on the labor market and the changing requirements in companies. Basically, it will be a matter of keeping job-related knowledge and skills up to date with the latest technological developments (cf. Dengler & Matthes, 2021; Acemoglu & Autor 2011). Employees may then have to demonstrate a greater willingness and ability to adapt by vocational education and training (VET) to be able to perform more complex activities that

[1] For further information about specific job changes through digital technologies in Germany see online tool 'Job-Futuromat' (Dengler et al, 2020), [online], https://job-futuromat.iab.de/en/.

are difficult to computerize, such as controlling and monitoring digitized work processes (cf. Trenerry et al, 2021; Harteis, 2019). At the same time, the educational stakeholders in vocational training are required to provide appropriate and suitable training provisions. Those should be used to develop the required skills and abilities with regard to dealing with new technologies. In addition, the training provisions will probably also have to be aimed increasingly at employees who, according to the Adult-Education-Survey Trend Report (Federal Ministry of Education and Research (BMBF), 2021), are relatively less likely to participate in VET, such as low-skilled and older employees or people with a migration background (cf. Siegfried & Berger, 2020). Moreover, in the course of digitalization, digital media will and should also be used through education at all levels to enable the use of new technologies not only in terms of content but also in practical terms.

In this context, serious games could be an effective tool, as they can convey learning content in a playful and motivating way. On the other hand, they can also evoke behavioral changes or simulate creative and interactive activities that are not subject to routine. They can also simulate complex real-life situations, such as the use of machines in non-routine situations, without disrupting operations. Apart from that, they enable personalized offers that can be adapted to the individual needs of the users and increase the learning motivation due to their playful character. Serious games could be used to develop the skills of the targeted employees at least to the level 5 of the German or European Qualifications Framework (DQR / EQF).

The practical problem is to find high-quality learning games for a specific job and skill level and finally to integrate them into an existing learning management system (LMS). The remaining of this paper presents the results of an in-depth analysis of classification systems for VET and a conceptual approach to use those classifications as well-defined terminology for search and retrieval of appropriate educational games.

2. Analysis of classification systems for vocational education and training

2.1 Starting point and current state of classifications

In Germany, classifications of occupations are used for statistics and analyses of the labor market or employment. Occupations or activities serve as an important indicator to classify employees and their position in the economy and society (cf. Federal Employment Agency [BA] 2020). In this context, the collected data are aggregated and classified in defined groups based on their similarity in terms of i.e. the main activity approach or other binding criteria (Dengler et al, 2014). Such a system of structured occupational data provides a detailed overview of comparable data to reflect the diversity of occupations and activities that is as close as possible to reality. In order to be able to investigate research questions in this regard, classification systems are developed that can be designed differently depending on the purpose of the survey (cf. Federal Statistical Office [Destatis], 2008). For this purpose, different systematics and classifications are presented and analyzed to identify a suitable occupational classification for this project.

2.2 Overview and results

An analyze of established and well-founded national and international classification systems is reported in this section. The research produced a total of four national and one international classification system (cf. Figure 1). Due to the small sample as a result of the literature search, an in-depth investigation of the classifications was undertaken. Therefore, the analysis is based on the following requirements: it should be a realistic and present representation of the diversity of occupations and activities in Germany, but it should give an adequate synopsis of occupational aggregates, there should be a link to the skill level and it should be compatible to international or other national classifications. The classifications presented partly build on each other but are often based on different structural principles. In addition, it should be considered, that they differ in the underlying definition of occupations and define different criteria for determining the similarity of activities or occupations.

CLASSIFICATION	DESCRIPTION
International Standard Classification of Occupations (ISCO-08) (ILO, 2016)	• Four-level hierarchically structured classification with 10 major groups, 43 sub-major groups, 130 minor groups and 436 unit groups. • *"Skill level"* is the primary dimension used to arrange occupations into major groups, within each major group the dimension *„skill specialization "* is used to arrange occupations into sub-levels. • Compatibility with the KldB 2010 via correspondence table, however, there are allocation problems, especially at the lowest levels (just approximation). • Internationally comparable occupational data, but no image of the real national labor market in Germany. • The major group level has proved to be not differentiated enough, sub-major group level is already too fine-grained.
German Classification of Occupations 2010 (KldB 2010) (BA, 2020)	• Five-level hierarchically structure classification with 10 occupational areas, 37 occupational main groups, 144 occupational groups, 702 occupational sub-groups, and 1,300 occupational types. • "Occupational / Skill specialization" (activities, knowledge, and skills) is the primary dimension used to arrange occupations on the first four levels of the classification. • The dimension "skill level" is used to arrange occupations on the last level, showing the complexity and range of tasks and duties to be performed in an occupation (similar to the ISCO-08). • The occupational types could be helpful for mappings according to the German or European Qualifications Framework (DQR/EQF), but with 1,300 positions the level is too detailed and fine-grained. • The dimension skill level could provide a starting point to identify occupations or jobs with main activity that are highly susceptible to computerization (those could have a particularly high need for digital and game-based learning opportunities). • Theory-based, uniform, up-to-date, realistic, national classification of occupations. • Comparability to the ISCO-08 and to previous national classifications (KldB 1975-1992) just via correspondence tables. • First level is no real occupational breakdown, but represents a thematic overview, with 37 positions the occupational main groups are already too fine-grained.
Occupational sectors and occupational segments (Matthes et al, 2015)	• Second-level hierarchically structure with 5 occupational sectors and 14 occupational segments. • Based on the second level of the KldB 2010 (aggregation of the 37 occupational main groups). • Using homogeneity analyses, the occupational main groups of the KldB 2010 (digit level 2) were arranged into occupational segments and sectors, on the basis of theoretical similarity of occupations to each other). • Each occupational segment includes a description of the main tasks and duties (not a standardized and verified procedure). • Further allocation dimension: number of employees dominating the labor market • Similar to the occupational field definition developed by the Federal Institute for Vocational Education and Training (BIBB).
Occupational fields of the Federal Institute for Vocational Education and Training (BIBB) (Tiemann, 2018; Tiemann et al, 2008)	• Third-level hierarchically structure with 3 occupational major fields, 12 or rather 20 occupational main fields and 50 occupational fields. • Using an identifier (linking the occupational groups [digit level 3] with the skill level [digit level 5] of the KldB 2010) to aggregate the occupations. • The primary dimension used to arrange occupations into groups is based on the similarity of main activity and industry focus (determined using microcensus and BIBB/BAuA employment survey). • Realistic and current structure: changes in occupations and activities are considered. • Verified, proved, long-term valid structure. • Compatibility with the concepts and occupational information in the KldB 2010; in addition, there is a reference back from the previous version of the occupational field definition in 2008 (that was based on the KldB 1992) to the development of the occupational main groups (digit level 2) in the KldB 2010.
German Classification of Economic Activities 2008 (WZ 2008) (Destatis, 2003, 2008, 2020)	• Multiple-level hierarchically structure with 21 sections, 88 divisions, 272 groups, 615 classes, 839 sub-classes. • The classification is based on the dimension main economic activity and products produced or services rendered by one or more business(es) or enterprises. • No occupational information, but classification based on industry or branch of business. • Can report changes, such as digitalization, in industries and economic structures.

Figure 1: Overview of established and well-founded national and international classification systems

Based on a detailed analysis and discussion[2], the classification of the occupational fields, as defined by the BIBB (Tiemann, 2018), can be recommended as a result. As other reviewed classifications, it is based on a well-founded development and has been repeatedly empirical tested. The primary dimension used to classify the

[2] For a further discussion of the presented classification systems see "Review of classifications of occupations", [online], https://serious-games-berufliche-bildung.de/downloads/.

occupations is based on the similarity of main activity and industry focus, which is determined using the statistical data collected by the annual microcensus[3] and BIBB / BAuA[4] Labor Force Surveys (ETB). Additionally, the developed occupational fields already reflect skill level, which describes the complexity of the activities to be performed. As the concept of the occupational fields is based on the KldB 2010, they are highly compatible and provide current specific occupational information from the expert database of the Federal Employment Agency. At the same time, the classification offers an acceptable and realistic overview of the national occupational structure of the German labor market, with 20 occupational main fields that present clearly defined content, and 50 more detailed occupational fields. Additionally, there is an international connection to the ISCO-08 and to other national classifications via correspondence tables. Thus, the BIBB classification best meets all requirements.

2.3 Detailed domain-specific academic debate

In addition to the summary of the overview presented above, this paragraph provides further domain-specific considerations about the review results, targeted for scientists in the educational sector.

In comparison, the national classification of occupations, KldB 2010 (BA, 2020), would be more suitable, as it presents the current occupational structure and realistically reflects developments on the labor market, as well as long-term changes over time. As the KldB 2010 is based on current occupational information from the expert database of the Federal Employment Agency, the classification is characterized by its practical relevance. At the same time, it is linked to ISCO-08 and thus compatible with international classifications, which is another important requirement. In the KldB 2010, the characteristic or dimension by which occupations are arranged into groups primarily is the dimension of skill specialization (activities, skills, and knowledge characterizing the occupation). Assuming that the increasing use of disruptive digital technologies will lead to changes in main activity within occupations and occupational fields, in particular, it could be useful to select a classification system that uses the main activity, for example. Also, regarding the determination of the VET profile and the associated self-location of interested people in their occupational field, the fitting criterion could be the main activity. Apart from that, the fifth level of the hierarchical structure of the KldB 2010, the dimension skill level, describes the complexity of the activities to be performed. This metadata could be used to determine the further vocational education and training profile of interested people: potential users could be located at their current qualification level, e.g., by asking for information on the qualification or skill level.

But a difficulty of the KldB 2010 could be the fact that the first hierarchical level, the occupational areas (digit level 1), provides more of a thematic overview. Therefore, it is intended to guarantee user-friendly handling of the classification than to correspond to the realistic occupational breakdown. In contrast, the second level, the occupational main groups (digit level 2) with 37 elements, is too detailed for the purpose of maintaining a moderate overview. In this context, the occupational segments and occupational sectors could be the better choice, as they are based on the KldB 2010, but provide 14 relatively clearly defined occupational aggregates (cf. Matthes et al, 2015). But in a closer comparison, the occupational fields or occupational main fields as defined by the BIBB would be more suitable. Those are also used in the QuBe project of the Federal Institute for Vocational Education and Training (BIBB) and the Institute for Labor Market and Career Research (IAB) to provide a long-term overview of the likely development of labor demand and supply in terms of qualifications and occupations.

Similar to the QuBe project[5], the SG4BB project will also identify users according to qualifications and occupations in order to locate them in their occupational field. For this purpose, the concept of identifiers has used that link the occupational groups [digit level 3] with the skill level [digit level 5] of the KldB 2010. Based on this concept occupations are aggregated according to their main activities. Therefore, the developed occupational fields already reflect skill level, but at the same time offer an acceptable overview with 20 occupational main fields with clearly defined content and 50 more detailed occupational fields. The dimension used to classify the occupations is based on the main activity defined by the microcensus and ETB. Like the occupational segments and sectors, the updated version of the occupational fields is based on the KldB 2010. Also, the microcensus and the ETB use the KldB 2010, which demonstrates high compatibility with national and international classifications.

[3] URL: https://www.it.nrw/sites/default/files/atoms/files/mz-fragebogen_2019_g_muster_englisch.pdf (last visited on 22nd June 2022).
[4] German Federal Institute for Occupational Safety and Health (BAuA)
[5] URL: https://www.bibb.de/en/11727.php (last visited on 22nd June 2022).

3. Conceptual approach towards a search engine for vocational education and training

3.1 Occupational fields as classification system for vocational education and training

From the educational perspective, the conceptual approach is based on the determination of a vocational training profile. Finally, a construct of three interrelated components has been elaborated, with respect to the definition of well-defined, machine-readable attribute lists for a search engine: occupational main fields, occupational fields and main activities (cf. Figure 2).

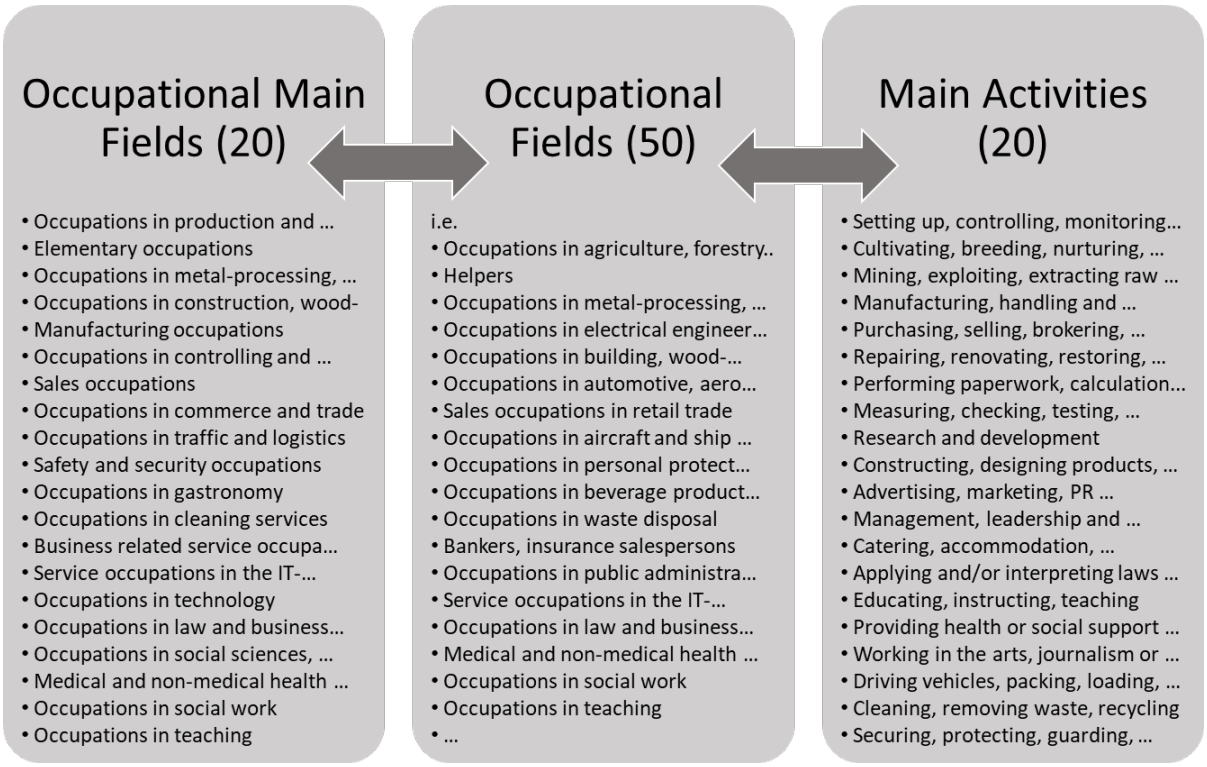


Figure 2: Interrelated components based on the classification of occupations

Based on the analysis of classification systems, the interrelation among occupational (main) fields, and main activities become obvious: the 50 occupational fields are grouped together in further 20 occupational main fields; thus, they present a manageable and practical overview of the national labor market. In turn, each occupational field is explicitly assigned to one of the 20 main activities and corresponding skill level. This enables interested people (or other educational stakeholders) to locate themselves in their individual occupational field and at the same time at their skill level and in their occupational main activity.

Technically speaking, the classification of occupations (Figure 2) and the matrix structure among occupational fields and educational games (Figure 3) allows search and retrieval of appropriate games for occupational fields: In the authoring phase, providers of educational games need to attribute the games with occupational fields and main fields. During the search and retrieval phase, the games can be identified by potential users using the search engine for VET (see next section) and occupational (main) fields and activities as search criteria. Hereby it needs to be stated that some games are fully dedicated to a particular occupational field and industrial focus (e.g. the 'Corrugated Service Game' tackling specific processes and machines for corrugated paper and boards), whereas other games such as the 'IT Security Game' covers more general topics and can be used in a broad range of occupational fields.

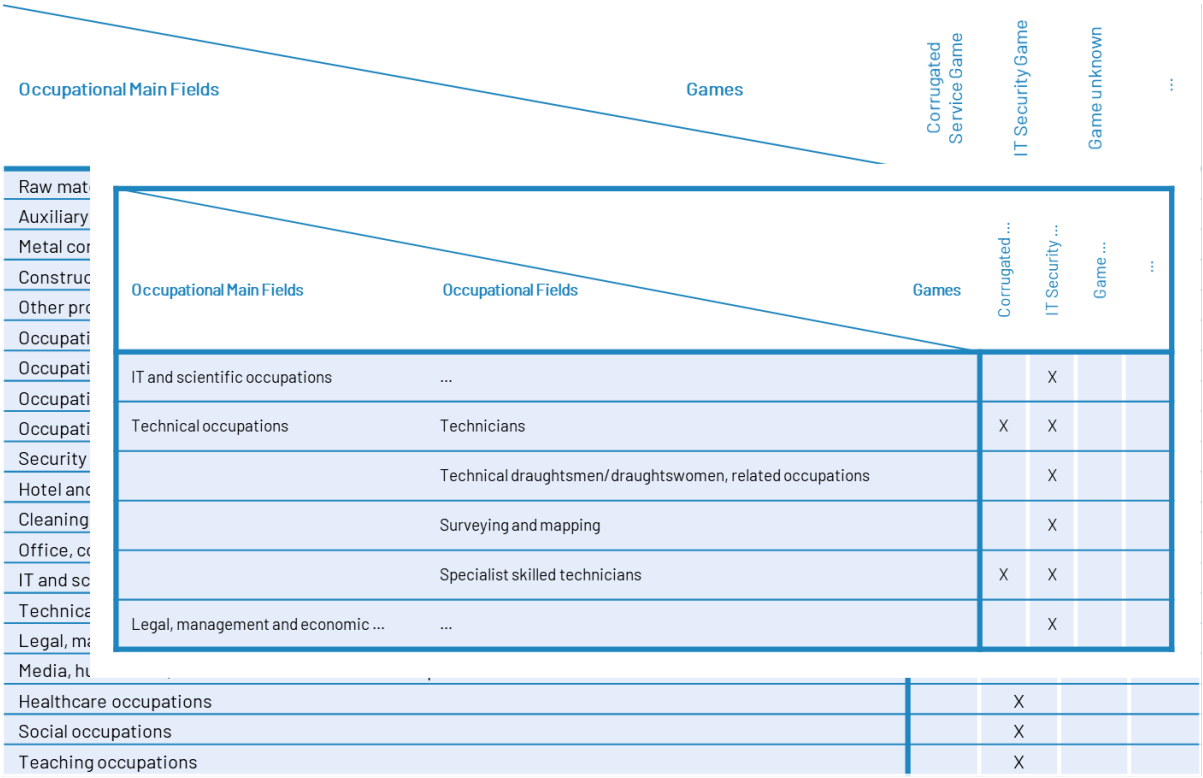


Figure 3: Matrix for occupational (main) fields and educational games

3.2 Search Engine for educational games for vocational education and training

The Serious Games Information Center (SG-IC) [6] offers a web portal for search and retrieval of serious games and educational games as a main application field of serious games (cf. Göbel et al., 2018). Game developers and publishers can use the SG-IC to describe their games. Vice versa, educators such as teachers, coaches or trainers and individual learners can use the portal to find appropriate educational games for their educational purposes and learning goals. The underlying semantic basis for search and retrieval is built by the so-called Serious Games Metadata-Format (SG-MDF), which has been published as DIN SPEC 91380 by the German body for standardization (DIN institute) and is available for free in electronic form via the Beuth publisher.[7] The SG-MDF and, subsequently, the SG-IC as search engine using the SG-MDF already offers an application profile for educational games, but that profile is not focused on vocational education and training and misses the well-defined terminology and classifications of occupations typically used in that application domain.



Figure 4: SG4BB pipe

For that, the public funded project "SG4BB – Serious Games for Vocational Education and Training" has been established with the overall aim to provide a platform for the use of serious games / educational games in VET. Figure 4 illustrates the process pipeline for the usage of the SG4BB platform: In a first step, learning providers, coaches or individual learners are seeking for appropriate learning material for a specific job / occupation. They can use the SG-IC metadata-based information system to formulate queries for serious games / educational games as game-based learning material. As search criteria, among other filters for specific occupational fields, main activities, a target age group or a game genre can be defined. As a result of the information retrieval process, a set of candidates (i.e. appropriate educational games, matching the search criteria of the formulated query) are listed in the SG-IC and can be analyzed in a detail view which provides all available metadata

[6] The SG-IC is a classical web-based information system in form of a portal. URL: https://seriousgames-portal.org (last visited on 17th June 2022).

[7] URL: https://www.beuth.de/en/technical-rule/din-spec-91380/289947896 (last visited on 3rd June 2022).

information (following the standardized SG-MDF format) for an educational game / serious game. Within the distribution section of the SG-MDF, users get information where the original games are available. Hence, users can follow the links and directly access the games via available download platforms, and integrate it within their learning environment (i.e. typically a learning management system). In SG4BB, by example, an interface between the SG-IC and the "Skillfire" platform – as "Steam-like" distribution platform for game-based learning and training material – has been built. Finally, as soon as the serious games / educational games have been used, the users / learners are invited to provide their (individual, subjective) feedback about a game and share it with the SG4BB open community. In the following parts this paper focuses on the first and second step of the pipeline. The development process of a middleware for the integration of educational games into existing LMS (such as moodle in SG4BB) as well as the data exchange and communication between the educational games and the LMS (based on the xAPI standard) are part of ongoing work in the SG4BB project and will be described in further research contributions.

3.3 Metadata-based application profile for vocational education and training

The SG-MDF (Göbel et al, 2011; 2018) as standardized description format (DIN SPEC 91380) for serious games provides a hierarchical "level" concept: Level 1 represents the "core" level with a set of mandatory descriptive metadata fields which are relevant for all domains and subdomains of serious games, among others education, training and simulation, health, marketing or awareness games. Level 2 provides additional optional metadata fields, also applicable for any serious games' application domain. Level 3 has been conceptualized for so-called "application profiles" providing additional metadata information fields relevant for specific application fields. In the available document of the SG-MDF two application profiles are already available: a profile for "education" and a profile for "health". Based on the application profile for educational games, within the context of the SG4BB project, another more detailed profile for vocational education and training has been elaborated. This profile provides metadata fields and pre-defined attribute lists for the specification of the characterizing goal of games for vocational training as well as the occupational (main) fields and main activities (cf. Figure 2). Those attribute lists with its well-defined terminology / classification systems support the information retrieval process to find appropriate educational games matching the needs of users / learners respectively learning providers.

3.4 Search Engine for educational games for vocational education and training

In a second step, the existing SG-IC has been extended according to the application profile for vocational training. This includes the extension of a metadata editor on the authoring side, enabling developers and publishers to describe their games based on the SG-MDF, and the extension of the search filters considering the attribute lists and classifications of occupations within the search process. More concrete, the new search filters include "vocational education and training" as one of the pre-defined application fields and all the occupation fields as possible search categories / keywords for application fields. These filter criteria are combined with any other keywords provided by users. As a result of the search process, users get a list of candidates / games matching the search parameters (cf. Figure 5a on the left side with two candidates). Based on the list of candidates, users can select the candidates and get a detailed view / metadata description of the game structured according to the SG-MDF (cf. example for the security game "Go Online" in Figure 5b).

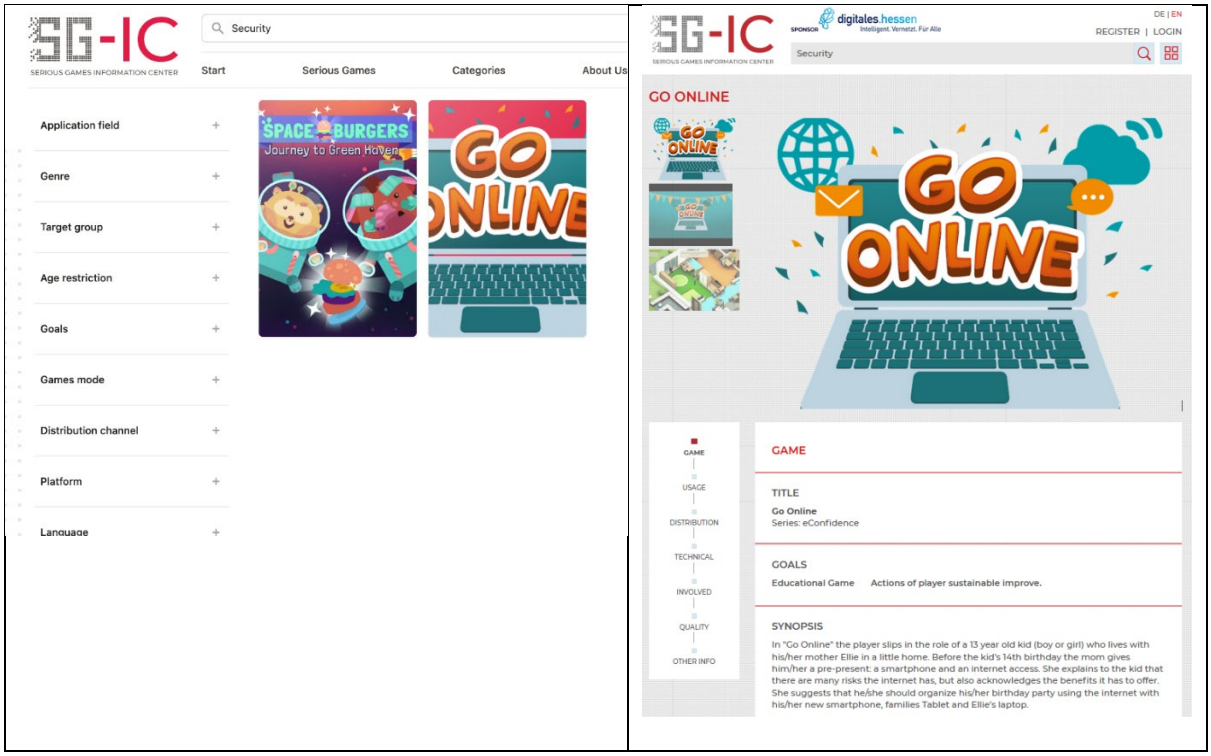


Figure 5: SG-IC portal search form with filters and keyword search (left) and a detailed view / metadata description of a specific game following the structure of the SG-MDF (right).

4. Conclusions

This paper presents a conceptual approach and practical solution in form of a metadata-based information / catalogue system to find appropriate serious games /educational games for (continuing) vocational education and training. On the conceptual side, a literature review has been undertaken to identify a classification of occupations that can be used as a database and fitting criterion to find and provide appropriate serious games / educational games in vocational education and training. A set of three interrelated classification fields has been identified: Occupational fields and occupational main fields plus main activities (relevant for the different occupational fields) (Tiemann, 2018). On the technical side, those classifications have been integrated into the SG-MDF as application profile "vocational education and training" and subsequently are used for the description and retrieval of games within the SG-IC. Therefore, the categories have to be precise, so the authors will be able to interpret them.

The elaborated concepts and its practical implementation are going to be tested within the SG4BB research project and will be available for the public starting in September 2022. Next steps will include the development of a middleware to download and integrate available educational games into learning environments (LMS). Hereby, the middleware will provide mechanisms for real-time communication among the games and LMS. On a second strand, the quality of educational games for vocational education and training will be analyzed according to quality criteria (Caserman et al., 2020). The results of those game studies will end in and further enhance the SG-MDF and SG-IC allowing potential users a better qualitative assessment of available learning appliances and will support their decision which one will be bought / licensed and integrated into a LMS.

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Gamification for the Development of Competencies in Tec21 Based on Mixed Reality

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Abstract: Currently, university students expect to obtain not only valuable knowledge about their majors, but they also want to develop different skills that will allow them to develop and stand out in the highly competitive world of work in which we find ourselves. To achieve this, Tecnologico de Monterrey implemented the Tec21 model, a challenge-based learning system focused on the development of both disciplinary and transversal competencies. Among the innovative tools used to promote these competencies we can find, after our research, the gamification: a technique that uses the resources of a game to promote student learning in an unconventional way, resulting in an excellent means for the development of the competencies. At the beginning of the pandemic, educational institutions reinvented themselves through innovation to make distance learning efficient. At Tecnologico de Monterrey, we have sought to develop problem-solving competencies through the implementation of two gamification strategies: an Enterprise Resource Planning (ERP) simulator that emulates the processes of a scale car model manufacturing line and a role-playing game in which students solve problems through a scenario. Three important factors were considered for gamification: engagement, academic rigor, and the development of competencies, all this has been enhanced with the use of emerging technologies such as immersive, augmented, and virtual reality, which allow students to have access to Laboratories at a distance and at any time. The theoretical concepts used, the situations or problems selected, the dynamics of the game, and the use of technological elements such as augmented reality and the use of the Tec Virtual Campus, have made this project an enrichment experience for the users, since the students spent an average of 32 hours of practice per week, improved their confidence in the application of problem-solving methodologies and developed teamwork, problem-solving, and information analysis skills. One of the greatest achievements, additional to the academic aspect, was the increased emotional stability of the students, which had been affected by episodes of depression derived from the confinement.

Keywords: Innovative education, gamification, problem-solving, higher education

1. Introduction

The Tecnologico de Monterrey has been characterized by constantly working to find academic excellence. Over the years, it has made various modifications to its syllabus with the aim of preparing professionals who are capable of adapting to the changing needs of society and facing the new challenges that arise. In this way, we have witnessed an important change in its educational model with the introduction of Tec21, a flexible model based on challenges that seeks to enhance transversal and discipline-specific skills.

However, the sanitary conditions caused by Covid-19 changed the world completely. In the educational field, both, the students and the teachers, were forced to use a virtual modality to which they were not accustomed, also, this fact represented difficulties in implementation: the students did not feel motivated by the way in which the topics were being presented causing a null participation in class, in addition the distractions were constantly manifested and, since most teachers were based on the tasks to promote learning, the students were saturated by the large number of activities, reaching the point to show signs of mental exhaustion and emotional disorders such as stress, anxiety, and depression.

The problem was clear, and an innovative solution had to be found, because if it continued like this, the students would not be involved in the activities that seek to promote the development of the transversal skills necessary to function in the professional world. To do this, different proposals were developed at the Tecnologico de Monterrey that, together, will represent an advance in an educational model based on a virtual implementation that faces the challenges caused by the health lockdown by covid19. Thanks to 30 years' experience in the design and teaching of digital education programs, in just one week of preparation and the suspension of academic activities for students, the institution resumed classes on March 23 through a Flexible and Digital Model designed to ensure educational continuity for more than 90 thousand students and 10 thousand professors.

The simulator itself, for students, is a very good learning tool, but in the context of confinement due to Covid-19, it was difficult to coincide with classmates at the same time, it was always seen as one more activity. On the other hand, one of the reasons why gamification was considered as a good tool to achieve engagement with students is the large amount of time young people spend playing games on different devices such as phones, computers, and consoles. Since the confinement, the popularity of video games increased as people turned to them to spend their free time. The research interns were able to notice this behavior because they were part of this group, and these observations allowed the teachers to consider gamification as a key element in gaining students' attention. It was in that moment that the leading teachers of the development involved the students in an empathy exercise and firstly added virtual augmented reality lessons, augmented and later inversive, achieving a learning addiction when the simulation was modified.

2. Previous work

Since 2015 the investigation group of the Tecnologico of Monterrey has been developing different innovations based on gamification and since 2019 they opened space for research assistants for engineering students with the aim of fully developing the empathy phase of *Design Thinking* by collaborating with the development of the educational innovations and the design of methodologies. It is in this way that the authors of this research are incorporated into all gamification initiatives that were being developed and as mentioned above, the MxREP simulator is the result of all the gamifications carried out in the area of industrial engineering since 2008. Gamifications have promoted the realization of 10 papers, of which this one stands out for presenting the results obtained with the implementation of this strategy in the new tec21 model.

2.1 Research approach

According to *Design Thinking* and Design of Experiment Methodology proposed by González, Lule and Caballero (2022) three factors were defined as the most significant in the research: the quantitative variable is defined as academic rigor, that means the learning of the techniques and methodologies in the industrial engineering. The qualitative variables were defined as competencies and engagement: the first one obeys to the development of disciplinary and transversal competencies in the Tec21 Model (reporte 2019- 2020), while the second one explained by the interest shown by the students in the class. Their relation can be seen in figure 1. To define the research variables, a form was applied to the students about their feelings about the health situation and distance learning.

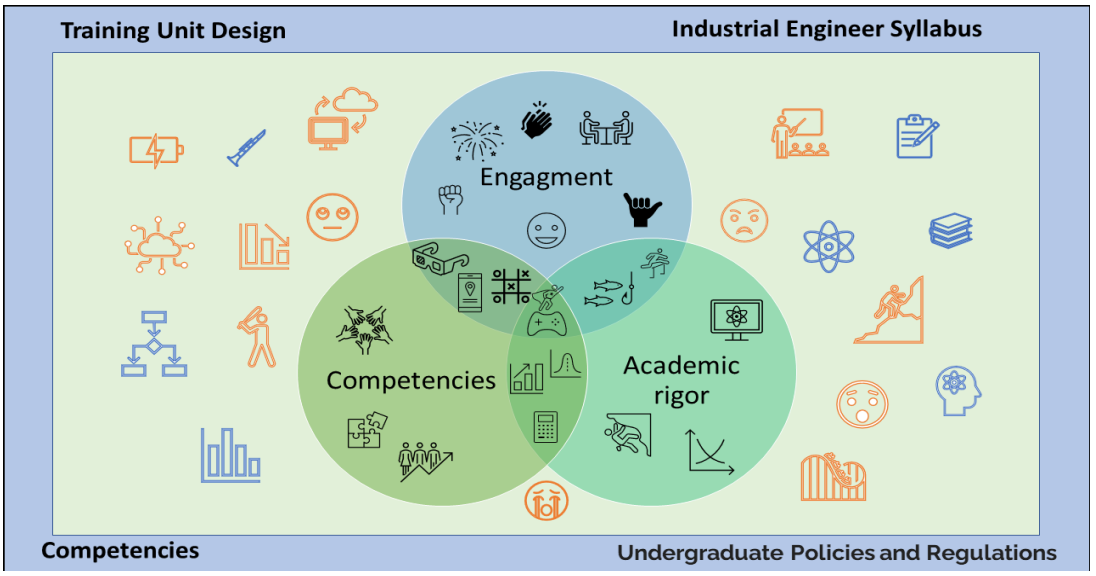


Figure 1: Design of the variables of interest through the DT & DOE methodology

In order to confirm that these three variables are met at the time of implementing the simulator, it was necessary to determine a research protocol in which the following was studied the veracity of the hypothesis that gamification increases the quality of learning.

A complete group of 36 students belonging to the course Improvement of an Organizational Process with Statistical Methods was selected. Two exams will be applied focused on the practice (topic) of which we want to

measure the knowledge acquired by the students. The first test will evaluate the knowledge previous to the use of the virtual plant (VEP) and the second after having carried out the practice to measure if there is greater learning and that it is statistically significant.

Based on the information gathered, a paired t student study will be carried out in which the following hypotheses will be studied:
H_0: $\mu_1=\mu_2$ The application of the simulator does not make a significant difference in learning.
H_1: $\mu_1\neq\mu_2$ The application of the simulator makes a significant difference in learning.

where:

- μ_1 is the population mean before the simulation
- μ_2 is the population mean after the simulation

2.2 Creative phase and first prototypes

One of the proposals to solve this issue was based on the development of a simulator of an ERP system focused on a car manufacturing company called, initially *Virtual Enterprise Planning* (VEP), but that after all the applied improvements and presentations it was considered that the most appropriate name would be *Mixed Reality Enterprise Planning* (MxREP), whose greatest strength is that it considers the company as a whole system and takes into account all the activities of the supply chain, unlike other simulators or activities that focus mainly on production planning. In addition, it contemplates the use of virtual and augmented reality, tools that give added value to students.

The algorithms of each process involved in the assembler were designed during the August-December 2020 semester, based on the Soft Systems Methodologies (SMM) for the definition the processes and the stakeholders involved (Checkland, P. B. (1989), and the Maltese cross (Wilson, B. 1980) was used to map the information flows for each process and then integrate it into a global ERP system. Concurrently, during this school period, a beta version of the simulator reinforced with augmented reality lessons that existed on the EON Reality platform (https://eonreality.com/) began to be used, specifically in the suspension of a car that was very similar to that of a racing car of the model 836560 104 111 multimodels of Meccano (Marriot, R. 2012) that are used in industrial engineering laboratories.

The first approach that the students had with the implementation of the virtual plant took place in the course of *Problem-Solving Methodologies IN3039*. In this, the learning obtained allowed them to observe several phenomena that were not considered within the conceptualization of the simulator, such as the emotional stability of the students during confinement, the frustration of not having real practices, as well as the time invested in the development of the activities and other considerations shown in Figure 2.

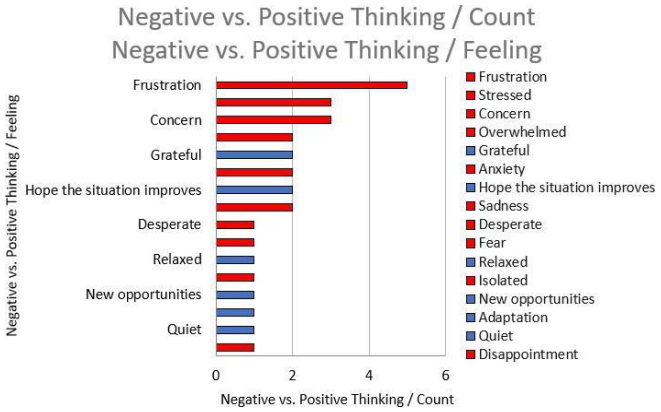


Figure 2: Students´ feelings of about the health situation

After the first implementation, a reflection analysis was made, and it found terrible results in the acceptance of students. The need for a redesign of the activity was imminent. The simulator was well designed but the activity should be transformed from tactical to strategic, in other words, do not focus on calculations and analysis with the use of different software, instead to design strategies to increase the company profits based on the teachings of industrial engineering topics.

The students were involved in the activities that allowed the idea for the VEP to be consolidated: from board games and car assembly in our statistics classes in the first years of the degree to gamification with virtual and augmented reality lessons. However, this development has not been an easy path and, as in any other project, problems were present at each stage from the conceptualization of the idea to the implementation of virtual tools. The concept and its objectives were clear, and it was even known what type of cars would be taken into account for the modeling. The Industrial Engineering department of the Querétaro campus of the Tecnologico de Monterrey had experienced working with Meccano assemblies in physics, like the one showed in Figure 3; the design of it, the total number of parts and their flexibility made them an attractive prototype to be considered as the model cars of our assembler. However, there was a significant delay in the development of the digital parts, lengthening the time for the tests to be carried out with the students. After solving this problem, up to five different models of cars and planes could be designed.



Figure 3: Digitized Meccano model

On the other hand, in order to establish a clear structure through a Bill of Materials (BOM), each of its parts was renamed and cataloged according to its nature, supplier, region and country of origin.

These elements were sufficient to define the *Stock Keeping Unit* (SKU) of each part of the models, which is a code that allows the management of parts and their traceability in the supply chain as it is used in reality with the aim of making the user experience more enriching.

3. From an efficient simulator to an exceptional gamification

As of February 2021, the research group focused on transforming an ERP simulator in which the students had a good learning experience into an educational innovation where the three research variables had the highest values, i.e., they were able to enter the success zone shown in figure 4. This was achieved by gamifying the simulator in an online platform that could be accessed from anywhere the student was and that would record their progress and the time spent to obtain the best results.

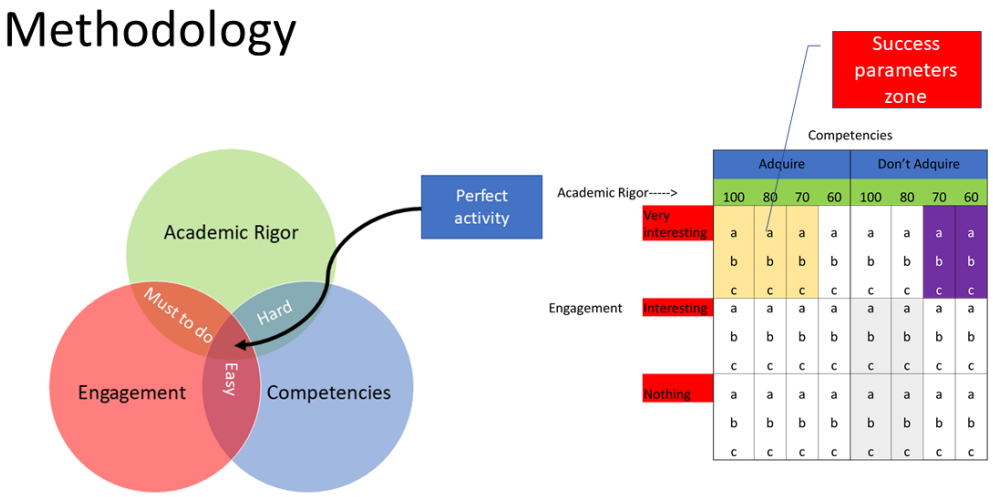


Figure 4: Factor to achieve success in an activity

With the use of the simulator, the most significant processes of a car assembly plant were represented (Figure 4), starting with the customer, who is the one who generates a purchase order that finally reaches the buyers of

materials. This is where the productivity index should be consulted, since if the purchase order is for 40 cars, it would be a mistake to buy the spare kits for that amount of product if the productivity index suggests buying more to counter design problems and quality that may arise during the process.

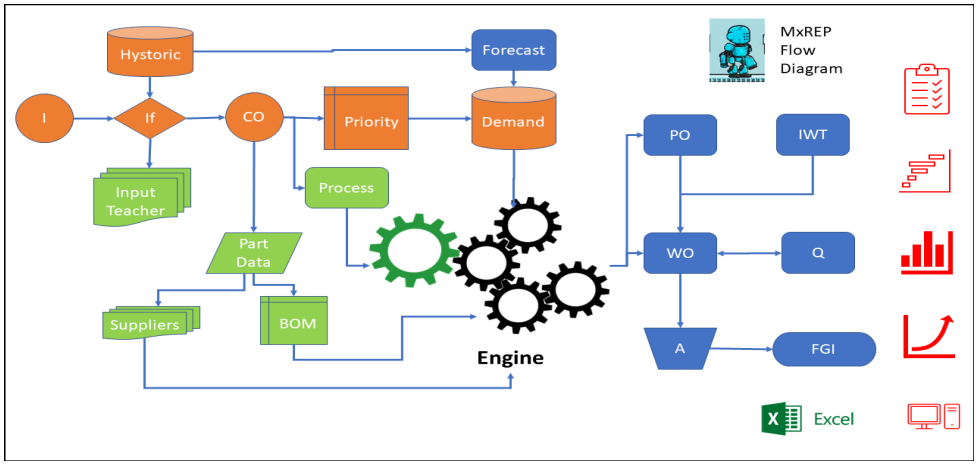


Figure 5: Simulator system design based on an ERP model

The incorporation of these different elements and modalities is very important for this project because we know that there are other systems that are similar to MxREP, but that lack points that give added value to our learning. In accordance with González et al (2021) at recognized universities such as MIT use "the beer game" to explain the fundamentals of supply chain management or the "Fishbank", a simulator that focuses on resource management, while Harvard students learn via the *Operation Management Simulation: Balancing Process Capacity* and the *Global Supply Chain Management*. The drawback that all these tools have in common is that they focus on a few specific areas, while MxREP, fostering systems thinking, considers the entire supply chain.

At this point, this simulator meets two of the variables (skills and academic rigor) of the *Design Thinking*, so to achieve student engagement, gamification is used, which “allows students to engage, improve their learning, and focus on learning objectives”. Its design is based on a model where they have challenges, objectives, and achievements in such a way that the user learns while having fun. This involves game elements such as prizes, competition between students, teamwork, and progress and scoring tables to drive engagement (Holloway, 2018).

For the simulator to be successful, it was placed on a 2D platform to create a gamification with graphic animations, this is because the nature of the human being is to be competitive, and gamification make attractive for the student to use the simulator, which allows him in a fun and educational way to manage and put learning into practice in the classroom.

Virtual and augmented reality modules were added so that the student could visualize all the components of the car and could make the virtual assembly, thus enhancing learning and we could emulate the practices both in the laboratories and in the training centers. manufacture of forming partners.

Studies have shown that VR and AR experiences have increased student motivation and helped them acquire research, critical thinking, problem-solving, and communication skills through collaborative exercises. The benefits of VR and AR technology are reflected in our students' results as learning achievements, better learning outcomes, increased motivation, and more positive attitudes. They demonstrate emotions of happiness as they "learn through the game" (Gonzalez et al, 2020).

According to Gartner Inc. (2008), there are various significant emerging technology trends. I have highlighted the technologies that will significantly affect companies, society, and people in the coming years. These include technologies that enable businesses and society to regain confidence in technology. AR technology is booming exponentially because its use in innovative educational applications in the classroom is increasingly prevalent, allowing students and teachers to "interact" more thoroughly in their activities and the teaching-learning process. In an institutional way, in Tecnologico de Monterrey, we are using the Flexible and Digital Model (Modelo Tec21, 2022). It is a challenge-based learning model that integrates innovative teaching strategies and

cutting-edge technologies. The model proposes a flexible and digital learning experience that emphasizes content, interaction, learning activities, technological tools, and evaluation.

Various research studies in the educational environment by Akçayır (2017) have shown that experiences with emerging technologies such as AR and VR have resulted in the following parameters (in descending order): learning advantages (43.75%), motivation (31.25%), ease of interaction (15.63%)), collaboration (18.75%), low costs (12.5%), learning (12.5%), just-in-time information (12.5%), in-place learning (9.38%), student-centered (9.38%), student care (9.38%), enjoyment (9.38%), exploration (12.5%), increased capacity for innovation (6.25%), positive attitude (6.25%), awareness (3.13%), anticipation (3.13%), and authenticity (3.13 %).

According to Gonzalez et al. (2021) the defined scope of the simulation was an assembly company of scale cars built with Meccano parts and those suggested by the EON XR platform for the Willys and Wrangler Rubicon Jeeps, as well as the engine and suspension assembly lessons. A final assembly plant and four sub-assemblies were conceptualized that will be in different cities, processes of the different areas of the company will be simulated and the students will have the role of consultant, where the company will inform them of a problematic situation, they will have to define the problem and intervene in the areas of the company involved to generate a solution proposal.

The design of attractive dynamics that keep the students' attention is an interesting challenge for the teacher (Kuo & Chuang, 2010), with the help of Meccano as a basis to generate these dynamics, it has been possible to make complete simulations of manufacturing processes that involve the analysis of the systems internal departments, such as design, purchasing, product engineering, quality, logistics, testing, finance, information systems departments, to name a few, and external systems that are regulations, standards, sources of financing, suppliers, clients, carriers, etc. where the student through role-playing using event cards and dice emulates the day to day of the manufacturing center (Holloway, 2018).

Using tablets, telephones, and computers, they can monitor the progress of the other departments in real-time. The purpose of the activity is teaching based on competencies, rather than the theoretical learning of a subject and that the student gets hooked through the game, assuming different roles and challenging their creativity and resilience. Using the simulation of a planning process, it is possible to optimize the whole supply chain in one model. The goal or target of this workshop version, this leads to dramatic cost reductions and improved customer satisfaction (Davis & Comeau, 2004).

Gamification by itself generates a feeling of competitiveness in the human being, in education it generates that same competitiveness focused on winning in academic activity through the development of strategies that allow the student to obtain points, and the development of said strategies is the assimilation of the concepts seen in class.

When we play a board game, we are motivated to win, this sense of competition makes it attractive to spend hours and hours in this activity. Transforming methodologies and problem situations into fun challenges we manage to engage students in the learning process. According to Gonzalez et al. (2020) the advantages of gamification are:

- Make learning fun and interactive
- Generate learning addiction.
- The student has the opportunity to see a real utility to the theory seen in traditional class.
- Provide immediate feedback.
- Gamification enhances the learning experience.

If gamification is the *front end* of a simulator that shows in a simple and fun way the information transaction between the entities of an organization, enhances student learning and forms a special connection between students and the teacher, but the trigger that makes a total engagement is the use of mixed platforms, such as virtual, augmented and mixed reality.

4. Results

Recently, the implementation of the simulator was carried out in the class of *Improvement of an Organizational Process with Statistical Methods*. A test of previous knowledge was applied so that, once the run is finished, we

can compare the results based on two variables: learning before (A MxREP) and after (D MxERP) running the simulation, all this through an analysis of experiments. A sample of 36 students was considered, and the data obtained by our survey is shown in Table 1:

Table 1: Descriptive statistics

Statistics										
Variable	N	N*	Mean	Standard error	Standard deviation	Minimum	Q1	Median	Q3	Maximum
A MxREV	36	0	81.22	3.22	19.31	13.00	79.25	87.00	100.00	100.00
D MxREv	36	0	97.472	0.870	5.218	87.000	100.00	100.00	100.00	100.00

The mean obtained before the activity in the simulator was 81.22. It should be noted that, on average, learning with the traditional classroom method is fine. However, we see a large difference between the maximum and minimum ratings obtained; before performing the activity, the minimum grade was 13 and this value increased to 87.

A student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed.

The hypothesis to be checked is that the average of the grades obtained in the exams, which for the study will be called "knowledge gain", is different between the two exams.
H_0: $\mu_1=\mu_2$ The application of the simulator does not make a significant difference in learning.
H_1: $\mu_1\neq\mu_2$ The application of the simulator makes a significant difference in learning.

where:

- μ_1 is the population mean before the simulation
- μ_2 is the population mean after the simulation

It is desired to reject the hypothesis Null H_0, which will be able to demonstrate the veracity of H_1 and validate the assumption that students improve their academic performance using the simulator in industrial engineering topics.

With the support of Minitab software, a student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed. The results are shown in Table 2.

Table 2: Results of the Test

Test	
T value	P-value
- 5.31	0.000

With the results of the student's t-test with two paired samples it can be proven that with a p-value of 0 and 95% confidence level H_0 can be rejected; therefore, it was found that the two means were different. Consequently, it can be concluded that learning acquired by students is greater when the simulator is applied.

In figure 6 we can see a boxplot compares the academic performance before an after the simulator. It is very clear that the variability before the activity is higher, and the grades seems to be lower in comparison with the ones obtained after the simulator.

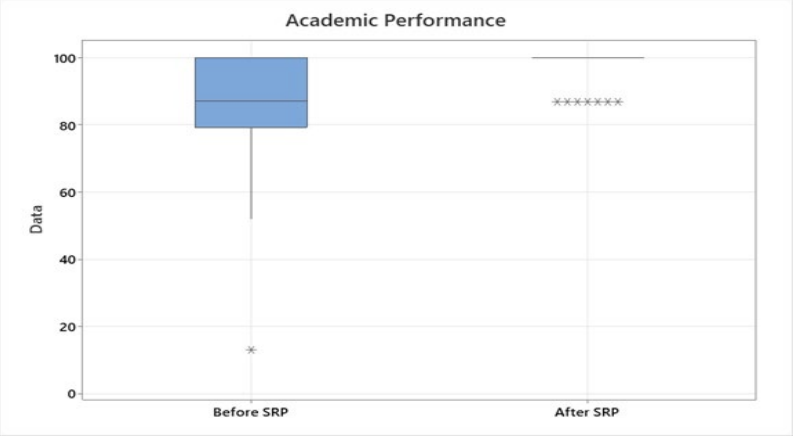


Figure 6: Boxplot before and after applying the simulator

In addition to the results presented above, non-quantifiable differences in the performance of this activity could be observed. It was possible to see the clear participation of all the students, even in some of the teams there were discussions about what was the best strategy to obtain the greatest benefits. Despite the fact that their involvement was noted, it was observed that they treated this activity as if it were another one, that is, there was a lack of emotion, which arrived at the moment of explaining how they would do the same activity but through the simulator.

5. Conclusions

Although the sole use of gamification in teaching shows good results, the use of the ERP simulator increases the student's engagement using virtual and augmented reality. Besides, the characteristics of the MxREP make it a useful tool for a diverse variety of courses since it integrates topics from Industrial and Mechanical Engineering.

Gamification causes an addition to the platform, and indirectly, the student begins to develop knowledge, moving from passive to active learning. We observed an improvement in the student's emotional stability, and satisfaction with the course is also observed.

As students, it has been a pleasure to collaborate in the design of improvements to the simulator. Our vision in two educational ways, as gamers and students, allowed us to provide feedback to teachers on design improvements. Before the research group opened its doors to assistants there was a disconnect between what the student expected from their classes and what the professor offered. The research interns became that liaison that changed the channel of communication and allowed for better learning. It should be remarked that this development was carried out under the auspices of the Institute for the Future of Education of the Tecnologico de Monterrey.

It is clear that the development of this simulator does not end here. Future objectives are to design cars, add data science and machine learning to create predictive models, making it a unique simulator in the market that could be used in other Universities. In addition, the research group plans to continue to allow the collaboration of students as assistants so that educational innovations can continue to develop with the valuable feedback they provide.

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Learning by Co-Designing Environmental (In)Justice Games

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Abstract: This paper describes undergraduate students' learning after researching environmental topics and co-creating and disseminating environmental justice games to fulfill their course and university service-learning requirements. Post-play reflections revealed motivation toward improvement in providing a game format that audiences would find engaging while learning about the seriousness of the environmental topic. Further, evidence of students' critical thinking, reflecting on the lack of environmental justice was noted. Students remarked that disseminating information by "spreading the word" is a key to raising awareness about environmental injustices. Essays also revealed students' intrigue with the game's co-creation process and enjoyed playing games with others. These findings may benefit researchers and educators interested in game creation as critical pedagogy.

Keywords: environmental justice education, co-creating games, critical pedagogy, constructionism, active learning

1. Introduction

Who is responsible for ocean cleanliness? What is the relationship between the location of hazardous waste sites and host communities' racial/socioeconomic composition? What is the environmental toll of uncontrolled wildfires? Who or what suffers for that 2-carat engagement ring? Which world nations constitutionally protect their environment? Why does a dichotomy of oppressors and oppressed exist in society? What laws protect the environment? How do we solve environmental problems? This study employed game-making as a learning strategy within the framework of critical pedagogy.

Critical pedagogy aims to raise learners' critical consciousness and awareness of their sociopolitical surroundings and fight against the status quo, with the intent of transformation both in the classroom and the larger society (Norton & Toohey, 2004). The study's process included researching, co-creating, testing, and disseminating/leading a game. First, in teams, students researched an environmental topic and delivered an oral presentation in a university environment. Students then co-created and tested their games in a university setting with the goal of improvement based on peer feedback. Finally, gameplay ensued at an approved public organization to educate about the environmental issue. Given that there is less research on materials development in critical pedagogy (e.g., Crookes, 2009; Norton & Toohey, 2004), this study presents one curricular option to immerse participants in game-making and reflection on learning so that they might assume active roles in, as Freire (1970) suggests, "transforming the world."

2. Literature Review

Game-based learning as a broad category has made significant strides over the past ten years, emerging as a powerful instructional strategy. Several empirical studies evaluating the impact of game use in varied disciplines show positive outcomes in student motivation and learning effectiveness (e.g., Papastergiou, 2009; Virvou, et al., 2005; Wouters et al., 2013). However, game development, or the *game creation process*, has received less attention compared to learning from game play (Engstrom, 2020; Weitze, 2021). Lack of interest in the game creation process may be associated with a trend in the literature of ignoring the author and focusing on the text and the readers' interpretations (Engstrom, 2020). Nevertheless, numerous researchers and scholars indicate that student learning through creating educational games is an emerging learning strategy showing promise (Earp, 2015; Kafai & Burke, 2015; Kuhmonen et al., 2019; Weitze, 2021). For example, one study at the post-secondary level revealed more satisfaction in learning course content through game design compared to more traditional methods. Further, the ability to discuss topics and network with peers during game co-creation was noted as a plus (Kuhmonen et al., 2019).

The current study employed a few conceptual frameworks that support educational game design as a learning strategy. The first conceptual framework is critical pedagogy, designed to encourage students to critique structures of power and oppression and encourage their participation toward solutions (Freire, 1970). In critical pedagogy, a teacher encourages students to question and challenge societal inequalities. Critical pedagogy discourse helps to demystify democratic authority or power and encourage a transformative discourse focused on equality (Freire, 1970). In his most celebrated tome, *Pedagogy of the Oppressed*, Freire (1970) argues against

traditional education's "banking" model in favor of a dialogic and problem-posing/problem-solving education. He objects to the traditional education frame in which students are "empty vessels" filled by the teacher (p. 79). Instead, he argues, education is to help students learn to think for themselves, solve problems, and participate in forming a more just society. However, emphasis must be on the processes involved in learning. Within the critical pedagogy framework, reflection on action is employed. Students reflect on their assumptions, beliefs, and understandings of the topics investigated. Kolb (1984) suggests that evaluating one's progress toward understanding is reflection, allowing the individual learner to form abstract concepts from their experience to guide active experimentation and inform future learning experiences.

Another framework employed in this study is constructionism. Papert's constructionism focuses on the art of learning and the significance of making things while learning (2008). Constructionism focuses on how learners engage in a conversation and social negation with their own or other people's artifacts and how these conversations boost self-directed learning and ultimately facilitate the construction of new knowledge. This learning theory stresses the importance of tools and media toward human development. It focuses on the processes through which individuals come to make sense of their experiences, gradually optimizing their interactions with the world (Papert, 2008).

Within the constructionist framework, an active learning pedagogical approach was employed. Active learning strategies and collaboration are student-centered in focus (Jonassen as cited in Maddux, Johnson, & Willis, 2001). Such types of instructional strategies serve as mental bridges for learning. As defined by Meyers and Jones (1993), student-centered active learning strategies provide opportunities for students to talk and listen, read, write, and reflect as they approach content in collaborative groups where students apply what they are learning.

The collaborative creation ("co-creation") process, where a team produces something that previously did not exist, is another active learning strategy employed to stimulate reflection. Sanders & Stappers (2008) explain, "The evolution in design research from a user-centered approach to co-designing is changing the roles of the designer, the researcher, and the person formerly known as the user" (p. 1). In this study, students worked with team members to co-create games. Co-creation engaged students in reflection through their consideration, reconsideration, and negotiation with the processes involved in developing their game for an intended audience. "Co-creation is more than a 21st-century phenomenon, utilizing which innovative solutions are being provided. The co-creation movement is a journey in the organizational transformation to the next paradigm of value creation – one that can lead to new growth and sources of competitive advantage" (Ramaswamy, 2009, p. 17). In addition, active participation in co-creation experiences can help prepare students for their future employment.

The game assignment under study consisted of activities in which students created and reflected on in their written and oral contributions of ideas and solutions toward envisioning the future and humankind's responsibility in helping to shape it. Activities involved student investigation of how they can contribute to a more compassionate and just world for humankind and the Earth itself; and promote just, healthy, and sustainable ways of living on our planet. In addition, embedded in the course is university required service-learning. Service-learning has emerged as a central component connecting disciplinary learning and general education to the public purpose (Felten & Clayton, 2011). Quality service-learning experiences offer students the opportunity to apply their knowledge and skills through an authentic experience. Moreover, well-designed service-learning experiences can facilitate the significant transformation of student perspectives and practices (Clayton & Ash, 2004). This transformation occurs when learners shift their frame of reference or belief system by critically reflecting on their assumptions, beliefs, and understandings of the world.

This study investigates if learning by designing and leading a game could foster reflections about environmental justice problems. Would the opportunities provided evoke students' awareness of humankind's responsibility in helping to shape the future? Does game creation have the power to move students toward contributing to a more compassionate and just world for humankind and the Earth itself?

3. Materials

Materials employed include discussions and activities about the purpose and mission of the United Nations and the Universal Declaration of Human Rights (UDHR), along with a comparative analysis of national constitutions

that have a concern for the environment. Another source was the United Nations 2030 Sustainable Development Goals, which sets an ambitious action plan for the U.N., its member states, and civil society. The games discussed in this article are specific to United Nations 2030 Sustainable Development Goals 6, 10, 12, 14, and 15 that address the environment (United Nations Department of Economic and Social Affairs, 2015). In addition, the class played the board game *(Go Goals!),* developed by the United Nations (2017). This game teaches players about the 2030 Sustainable Development Goals and stands as a model for participants when developing their own games.

4. Method

This study uses a qualitative content analysis with a convenience sample to examine the development of awareness of environmental injustices through the lens of a co-created tabletop game. Content analysis is well suited for analyzing and summarizing exploratory research data (Babbie, 2007).

5. Participants

In a general education course at a private university in the mid-Atlantic region (USA), undergraduate honors students (n=19) researched a specific environmental justice issue, co-developed a game, game tested with peers, and led game play with the general public. Participants included 16 females and three males, ages 19-21, of varied majors (e.g., nursing, finance, accounting, English, graphic design) and ethnicities. None of the participants had any prior experience with game development however, one student is planning a career as a graphic designer.

6. Instruments

This study employs two modes of inquiry. Mode one is the collaboratively developed game and components. The second mode of inquiry is the reflective essays. The essay was based on the writing prompt, "*Please document your thoughts about the environmental topic; your main learning takeaways, and your thoughts about the co-creation game development process and game dissemination at the community organization*."

7. Procedures

Environmental topics were explored for three weeks via assigned readings and videos, class discussion, small group activities, tabletop games, and independent reflective writing responses. Sample environmental topics discussed were the effects of microplastics, mining, carbon emissions, pesticides, deforestation, and ocean pollution on the environment.

Working in teams of 4-5, participants researched and presented on an environmental topic, co-designed a tabletop game, game tested, and developed a final version of an environment game. Details of the assignment began by providing participants with a list of environmental topics for their consideration. Guidelines required a 30-minute group oral presentation on the chosen topic. Feedback on the presentation content provided students with an opportunity to further direct their research for the game development. Games were developed over three weeks. Then, each game was tested by peers during class. Peer feedback was offered to each team. The game testing provided participants the opportunity to reflect on their assumptions and beliefs about the topic and consider the ability of their game to effectively communicate knowledge to its players. Gameplay was led by teams at a community organization in weeks 10 and 11, and the final reflective essays were due in week 12.

8. Data Analysis

This study employed a qualitative content analysis with a convenience sample to examine the development of awareness of environmental injustices through the lens of a co-created tabletop game. Upon conclusion of the game unit, the researcher collected the game boards, game components, and participants' final written reflective essays.

The reflective essays were read and used to develop themes. Examination of the final essays revealed the following broad themes*: learning about environmental issues through game design, learning about game design through game testing, learning to value others through co-creation,* and *learning about the power of game dissemination.* Below are excerpts from students' essays associated with each theme.

8.1 Learning about Environmental Issues Through Game Design

The following sub-themes emerged from post-play reflective essays: *growing awareness of environmental issues, associated hazards,* and *possible solutions.* The following excerpts are examples that provide evidence of these sub-themes.

R.P (Diamond Mining) "This experience - researching and creating a game revolving around diamond mining - helped me become more aware of the negative effects on the health of humans and the environment. Before this project, I knew there were lab and natural diamonds on the market. However, I was unaware of the importance of the shift we must make as responsible humans from natural diamonds to artificial diamonds."

S.V. (Ocean Microplastics) "Researching ocean microplastics and their effect on marine life has been enlightening yet disturbing and concerning. Plastic and ocean pollution are discussed in society, but not nearly as much as they should be. Furthermore, it is costly to manage pollution. Therefore, it would make more sense to revamp waste and plastic disposal systems and recycling techniques sooner, as these are long-term solutions to ocean pollution."

Y.A. (Environmental Racism) "One of my main take-aways was how environmental racism occurs in minority groups, noting that certain areas that experience the most health disparities also happen to be the areas that experience environmental discrimination. As a student nurse, I am now more aware that the environment one lives in has a great impact on one's health. It is heartbreaking to see that minority groups are marginalized for their skin color, but that it also has a greater effect on their lives concerning health -- as if their psyches have not already had enough."

J.R. (Wildfires) "Before researching this project and game, I was slightly educated on wildfires in the United States. However, many fast-spreading, dangerous wildfires have hit the western U.S. and Canada within the last five years. The main takeaways from this research and game development were that the policies around wildfires are lacking, and they need to be created to protect American citizens and our land."

8.2 Learning about Game Design Through Game Testing

Participants observed their games tested by peers in during class. Teams made notes about possible *game improvements* based on issues they observed during peer testing. Following are descriptions of the changes made by teams, evidenced in the final version of the game and the accompanying reflective essays.

The ocean microplastics team changed their crossword puzzle, revealing a few issues during the game testing. First, the team adjusted the sizes of boxes that were too small and the numbering within the boxes. In addition, discussion ensued about the need to include a word bank as the team was reminded that they needed to lead the gameplay in the next step of the project, game dissemination at a community organization.

The game testing session for the wildfires group revealed that their questions were too high level for the players to answer. After the game test, the team discussed all game questions, deciding which to revise or replace. The team determined they needed to provide some pre-play information about wildfires when disseminating their game at their chosen community organization.

The environmental racism game team noted that some players had difficulty reaching a new area on the game board because they kept landing in a "risk" section (outlined in dotted lines – see Figure 1). However, a group discussion taught them that this was a good thing because just as it was difficult for the player to move on to a new area, it was difficult for the people who lived in these areas to move on. In other words, players could perhaps experience empathy through gameplay. Therefore, they decided to keep the gameplay "as is" for the game dissemination event.



Figure 1: Environmental Racism Game Board

The diamond mining squad observed that some of their peers never landed on a designated spot during testing, so they did not have questions posed to them during the game (Figure 2). The team met and changed the game board and questions based on feedback. All questions were reviewed for applicability to their intended third-grade audience (ages 8-9). Figure 3 shows that the team added ten more question spots to the board, indicated by a "mining tools" icon to make the game more interactive. The team also divided the icons on the game board (i.e., diamond ring and mining tools) into true/false and multiple-choice questions. In addition, the team developed a small presentation so that the third-grade students would have some prior knowledge about diamond mining before gameplay. In total, thirty question cards were made for the game. The student who plans a career in graphic design developed the game board.



Figure 2: Original Diamond Mining Game Board

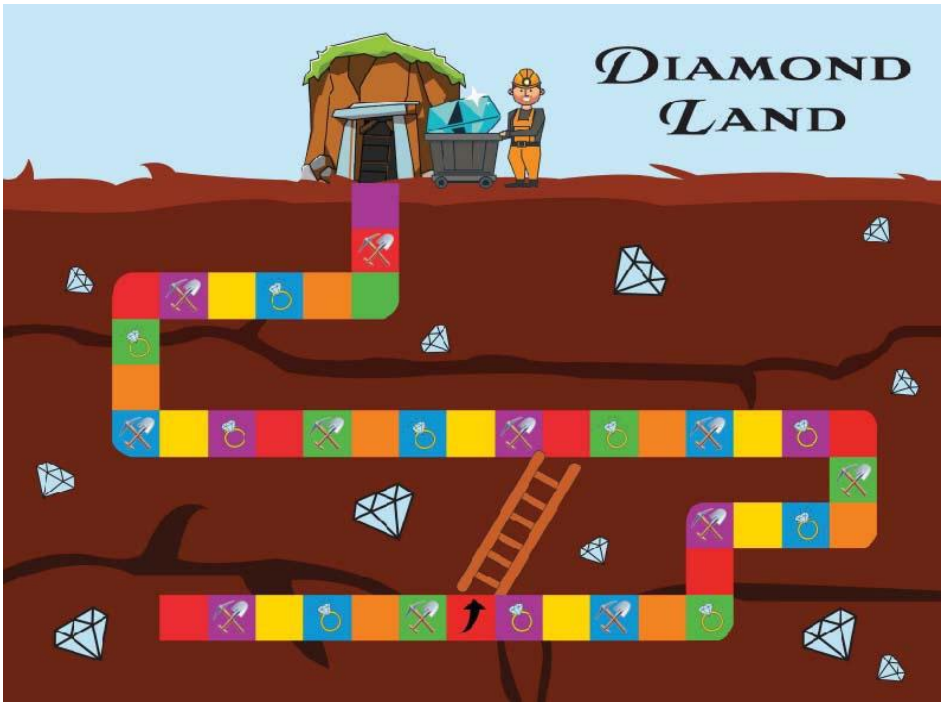


Figure 3: Final Diamond Mining Game Board

8.3 Learning to Value Others through Co-Creation

The following sub-themes emerged from post-play reflective essays under the broad category of learning through co-creation: *game development was a novel and creative experience; problem-solving skills were improved; collaboration was the key to game development success* and *developing engagement strategies to evoke player empathy.* The following excerpts are examples that provide evidence of these sub-themes.

A.M. (Diamond Mining) "College students do not get many opportunities to create unique projects like board games. I gained many useful life skills and information from this experience, such as collaborating with groupmates and adjusting language to a young audience. Our game, dubbed Diamond Land, was both an enjoyable experience and one that tested me in new and interesting ways. The hardest phase of game-making as a business major in finance was determining the content and making the questions fit a third-grade audience. It was difficult for me to articulate my thoughts so that young children would understand. I relied on my team members for assistance in this area."

J.M. (Environmental Racism) "The game creation process was a little difficult for me, given that this is such a serious topic. At first, it almost felt wrong to make a "game" out of it. Then I realized that just because it is a serious topic does not mean that the education about it must be dark and serious. Most people do not learn the best that way, so together we decided to make a board game about the harsh realities of environmental racism. We decided that creating a mixture of multiple choice and open response questions was the best option to ensure people learned and thought about the topic. The questions varied from the health and mental effects of environmental racism to advocacy ideas and laws. We also included "danger zones," which described real places in the United States and real things happening in these areas. This inclusion was to show that when people end up here, they can feel stuck, and many things happening to them are just unfair."

S.C. (Wildfires)"The game development process was based on team efficiency and sub-topic equality. We knew our game would be played virtually, making it more adaptable for the audience due to the pandemic. Therefore, we looked for ways to collaborate and represent each wildfire sub-topic equally; wildfires and their impact on land and air, children, minorities, the elderly, and policies. This way, we had enough representation of questions regarding each sub-category, allowing the players to get a better overall grasp of the topic".

8.4 Learning About the Power of Game Dissemination

The following themes emerged from post-play reflective essays under the broad category of learning about the power of game dissemination. The sub-themes are *spreading information is key to raising awareness, games*

can be fun and informational, and *leading a game fosters more profound knowledge.* The following excerpts are examples that provide evidence of these sub-themes.

R.L. (Ocean Microplastics) "As a result of our game development and play, more people now know what can be done to counteract ocean pollution at an individual and organizational level and will hopefully continue to spread knowledge. It is imperative to be educated on topics like this one because it is something that will not necessarily impact current but rather younger generations. Sometimes we are blinded by these global problems because we do not want to feel responsible, but we are. But we hide. Spreading the word is the first step to changing our world; therefore, we need to keep talking about what needs to be done."

E.J. (Diamond Mining) "I think this process was interesting and unique. I am not going into the teaching field yet being able to impact a younger group (3rd graders) was a nice change of pace for me and gave me a sense of joy. I saw young students take to the topic and think about how to fix the presented problem. To conclude, I liked how this project was presented to us; we could take it and run with it. We were able to create a game about a topic the group felt strongly about and then got out into the community and made some of the younger generation aware of a current topic and how solutions are addressed. As knowledge on this topic develops, these kids will be able to grow in their understanding and tell others about it!"

A.M. (Diamond Mining) "Having students pair up during play made the experience enjoyable for them, as they quietly deliberated over the answers. Students also got to share the highs and lows of answering questions. Some questions were worded in difficult ways for the students to understand, so we had to improvise and reexplain or reword a question or two so that the 3rd-grade players would comprehend. The students seemed to have a great time playing the game and learning a lot of new things. Honestly, the students did not seem to know anything about diamond mining. One student said, "I do not know anything about Africa."

S.H. (Diamond Mining) Being able to extend this research project to a game design and audience made it feel like a beneficial assignment. In school settings, it is so typical to delve into a research, write a paper, and submit it for a grade and that is the end of it. It seems wasteful. All that work! In this project, we were able to do something with the information by designing a game and presenting it to our peers and then play it with an audience. It was super rewarding."

J.M. (Environmental Racism) "During gameplay with our audience (university faculty, administrators, and students), it was clear players lacked knowledge regarding environmental racism. Some questions were admittingly difficult, and some players even felt ashamed for not knowing or being aware of the real-life issues this type of racism is causing. It was interesting to see university faculty and administrators play while learning about the United Nations Sustainable Developments Goals, the Universal Declaration of Human Rights articles, and one country's constitution. We felt that our game modeled a just and inclusive environment—our game night connected with the campus Diversity and Inclusion student club. Players were very interested in our game and wanted to meet again to play and discuss this topic further. I love that a class project had the power to help others by teaching them about environmental racism. We put a lot of time and dedication into the game development. It is great that other people want to continue using this game to raise awareness because awareness and advocacy are the most important parts of creating change. I enjoyed this investigation because I could educate myself, and now, I can educate those around me and hopefully spark change."

8.5 Limitations

This study reports on the results of a small-scale, case study research project in which the collected data focuses on content analysis and participants' reflections.

9. Discussion

Offering a game development option within the frame of critical pedagogy and constructionism to participants who knew nothing about the game development process and little about environmental issues provided them with a novel experience. Based on the reflective essays, most participants reported this as a unique creative assignment, and most reported they liked working with others on a team. Participants became more aware of environmental injustices through conducting scholarly research and co-creating a game. Preparing to lead the game with others created an additional depth to participants' learning as it required team members to review and reformat some game questions. This preparation facilitated deeper learning about the environmental topic.

This finding is similar to a study (Kuhmonen et al., 2019). In addition, pride was mentioned numerous times by participants upon the close of the game development project.

The feedback from the reflective essays revealed that students' frames of reference shifted due to this game project; most participants mentioned not knowing anything about this topic at the outset. Other participants said that although they had some knowledge about the topic, they now possessed more knowledge that enabled them to teach others. Through research and game development, students' critical consciousness emerged along with discovering societal inequalities, the dichotomy of oppressors and the oppressed, and the lack of clarity of the laws and policies designed to protect the environment.

The role of the game developer remains in question regarding the ability to articulate their message and meaning to others, which at least four participants similarly expressed in this study. Each of these participants indicated that they needed to collaborate with others to express clarity of thought. Although none of the participants in this study plan for a career in game development, it is essential to note that all people can sometimes experience articulation difficulties. Therefore, collaboration should be encouraged and rewarded. Unfortunately, this view is not pervasive in game development. Instead, technical expertise is favored (Whitson, 2020, p. 283). Messiness, including social conflict and skill-building does not fit with the larger cultural discourses of what game development is supposed to look like. So, it is largely ignored, thus replicating and perpetuating blind spots in the game development literature (p. 283).

10. Conclusion

Well-designed experiences can facilitate the transformation of student perspectives and practices (Clayton & Ash, 2004), occurring when learners shift their frame of reference or belief system by critically reflecting on their assumptions, beliefs, and understandings of the world. The general education course in which this study took place allows for consideration of inequalities and injustices in society. The gaming unit focused on the environment so students could become aware of the issues surrounding ocean cleanliness, environmental racism, the environmental and human toll of uncontrolled wildfires, and the human suffering and environmental degradation caused by diamond mining. Through active learning and reflection pedagogy, students saw the dichotomy of oppressors and the oppressed. They investigated the laws or lack of laws that protect the environment and people —employing a framework of critical pedagogy, which spotlights social realities allowing for the intended learning to occur. It is hoped that the environmental issues that were learned during game co-creation enables students to use this knowledge, not “just store it in their heads so that twelve years later it's going to be good for them” (Papert, 1990).

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Understanding the Elements of Challenge and Skills in Educational Games

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Abstract: Although researchers suggest that games have a positive experience in a learning outcome, there is still a lack of investigation on the potential of game mechanics for better flow experience and learning outcome. According to the literature, the flow state in the game creates player engagement which leads to a positive learning outcome. Based on flow theory, challenge and abilities are two crucial game elements to achieve a flow state. This paper discusses the importance of conflict and competition in generating challenges. In gameplay, the players use their abilities demanded by the game to complete the challenge. This paper discusses the role of different skills required to play the game, and through these abilities, the players learn. This paper explains the correlation between challenge and various skills needed to play games. Conflict can be the better approach to generate the challenge because it is endogenous. Knowledge is a crucial ability to incorporate into educational games. This paper also explains the role of prior knowledge, and it is observed that the player achieves a better learning outcome if the game demands some level of prior knowledge to play the game.

Keywords: Challenge, Conflict, Competition, Abilities, Knowledge

1. Introduction

Games designed for a primary objective other than pure entertainment are called serious games. As the nature of the games has changed dramatically, the researchers are focusing on the potential of games. The main objective of educational games is to help the player to construct knowledge about academic concepts and to train certain skills. Games-based Learning (GBL) has developed a reputation among educationalists; it is perceived as a potentially engaging form of supplementary learning that could enhance the educational process and has been used at all levels of education (Hou and Li, 2014) (Mahmoudi *et al.*, 2015). Despite this recognition, there is still a lack of empirical evidence supporting the relationship between attributes of games with learning attributes.

Opening up the 'black box' of games would enable us to focus on specific principles or mechanisms. This finer-grained approach could unlock the relationship between game elements and learning. Most of the papers discussed motivation, engagement, and flow (Hamari *et al.*, 2016) of the game. Still, these papers did not mention what kind of variables of game mechanics like motor skills, strategy, knowledge, memory, and chance were involved in the game and its correlation with learning achievement. It is required to establish the relationship between academic achievement and game-based learning (Sepehr and Head, 2018). Efforts are needed to articulate clear relations between variables of game mechanics and a range of outcomes, from a broad level and gradually narrowing down to specific gameplay mechanics.

The main functionality of the game is the challenge. Games must be challenging to engage and immerse the players in the gameplay. Based on the game definitions, a game is built as an activity. While designing the games for education, the designers develop the activity first based on the educational topic. Later, the game elements are incorporated to generate interaction between players, randomness, uncertainty, etc., to make an activity challenging. This activity in educational games will be related to academic topics and other abilities. The appropriate challenge in the activity is important in games. Some papers state that educational game with appropriate challenge retrieves learning outcome. The balance of challenge and skill is very important to achieve the flow state. On the broader level, competition and conflict can be used to generate challenges. This paper explains the role of competition and conflict in gameplay in educational games. It also explains the different types of abilities the game demands and the prior knowledge in educational games.

2. Flow Experience

There are theories in the literature that discuss the importance of flow experience in educational games. Malone and Lepper introduced a taxonomy with two parts that work together for intrinsic motivation in educational environments: individual motivation and interpersonal motivation (Malone and Lepper, 2021). Individual motivations include challenge, curiosity, control, and fantasy. Interpersonal motivations focus on the

relationship between the players, which have cooperation, competition, and recognition. As per Malone and Lepper taxonomy, combining individual and interpersonal factors leads to the player experience. This Self-determination theory is fundamentally concerned with well-being, but later it was extended to player experience (Ryan, Rigby and Przybylski, 2006). According to self-determination theory, enjoyment is derived from playing games that rely on three basic psychological needs: 'Autonomy' describes the need to feel that one is in control over their own life and that one's actions are self-endorsed. 'Competence' is the need to act effectively and feel capable in one's activities. 'Relatedness' is the sense that one is within the game world. Flow state is regarded as the ideal condition of mind and body, accompanied by immersion and enjoyment. The flow channel, with its optimal balance between challenge and skill, is the actual definition of competence in Self-determination theory. Self-determination theory seems to be an approach for making predictions about the quality of motivation, whereas flow is the autotelic experience, a concept related to intrinsic motivation and engagement.

Mihaly Csikszentmihalyi explains happiness and engagement as a state of "flow". According to Csikszentmihalyi, flow is a state of complete absorption or engagement in an activity and refers to the optimal experience (Csikszentmihalyi, 1990). Later on, researchers devised a set of theories to assist people in entering the flow state (Kiili and T Lainema, 2008) (Jennett *et al.*, 2008). Since then, these theories have been applied to various domains, including game design, to create better human interactive experiences. The flow can be considered an important factor of player engagement in game design. Researchers developed different game design frameworks based on flow theory (Kiili, 2005). According to Csikszentmihalyi's research and observations, the flow has eight major components: 1. a challenging activity requiring skill, 2. a task with clear goals, 3. a task that provides direct and immediate feedback, 4. a sense of control, 5. merging of action and awareness, 6. concentration on the task at hand, 7. the loss of self-consciousness, and 8. an altered sense of time. The designer must fulfill the first five components in the game to make players achieve a flow experience because they are the objectives. If the game satisfies the first five components, then the player experiences the other three components, showing that the player is in the flow state. The first component of the concept of flow is 'challenging activity requiring skill'. As mentioned above, the balance between the challenge involved in the game and the abilities of the player is most important to experience a flow state. So, identifying the mechanisms to create challenge is important to understand its effect on learning outcome of educational games.

As all the theories mentioned the importance of challenge, this paper focuses on understanding the challenge. According to the above theories, the challenge is an important concept involving the game system and players. Due to the involvement of the player, the skills required to win the challenge also have to be considered to understand the elements of challenge in games (Vahlo and Karhulahti, 2020). Flow theory is incorporated into game design to address the various skill levels players possess when performing a task or activity. So, Flow theory is used to understand the mechanisms to create a challenge because it focuses entirely on the challenge and its correlation with skills.

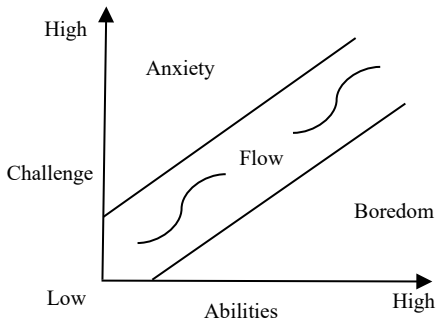


Figure 1: Flow in single-player games

Although challenges and difficulty are related, the two terms should not be used synonymously. As an analytical concept, the challenge can be thought of as a task or a problem, the difficulty is determined by the performer's abilities, knowledge, and skills (Iversen, 2012). The activity in the game is itself a challenge for the player. In the case of single-player games like Bubble Shoot, the challenge is to shoot the bubble with the same color. Shooting the bubble requires a certain angle and strategy to get more bubbles in one shot. In some games like Candy Crush, completing the game within the time limit or number of moves is the challenge. But perspective towards the challenge is different when other players are involved in the gameplay, i.e., multi-player games. Another

way to generate challenge that is through uncertainty. The uncertainty can be caused by including chance through dice or randomness.

3. Challenge

Many researchers tried to explain challenges and the role of challenges in educational games. According to the literature, the challenge in games positively affects learning directly and via increased engagement (Hamari *et al.*, 2016). The challenge in the game is a strong predictor of learning outcomes. For the designers of educational games, the results suggest that the challenge in the game should be able to keep up with the learner's growing abilities to endorse continued learning in game-based learning environments.

There are different types of challenges specific to that particular game. In the case of multi-player games, beating the skills of the opponent is a bigger challenge than the in-game task difficulty. In Chess, the player tries to win over the opponent player's strategy. In Scrabble, it is the player's knowledge versus opponent's knowledge.

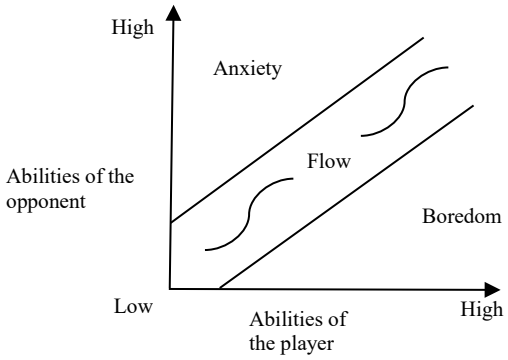


Figure 2: Flow in multi-player games

Based on the above figures, on a broader level, the challenge consists of two elements: competition and conflict. One common feature of game definitions is the inclusion of conflict or competition. There are numerous ways to formulate this and emphasize subtle differences, from underlining the agony between players to emphasizing the struggle participants must engage. Dempsey side-step the competition definition by deciding that it is possible to compete with oneself (Dempsey, 2002). Abt's definition specifies achieving objectives in a limiting context is called conflict with the game world (Dempsey *et al.*, 2002). Salen and Zimmerman's conflict is any problem artificially created by the game designer for the player to solve (Salen and Zimmerman, 2004). These definitions show that competition and conflict are essential elements in defining games. Even Malone and Lepper's taxonomy discusses competition as interpersonal motivation. They discussed three types of interaction between the players: Cooperation, Exogenous and Endogenous competition, and Recognition (Malone and Lepper, 2021). A combination of individual motivating factors and interpersonal factors work together for motivation in educational games.

3.1 Competition

Competition is an extrinsic element of the challenge in the game. In single-player games, competition is generated with external limitations such as timer, points, number of moves, and resources. As all the validations concerning external constraints are done at the end of the gameplay. So, competition is the end game element of challenge. In competition, the opponent's actions do not have any effect on the player's gameplay, but it has an impact on the winning outcome of the game. For example, in snake and ladder, players do not affect each other's gameplay, but in the end, the player who reaches first is the winner.

Competition with self. The players compete with their scores. This type of competition can be observed in single-player digital games but not in board games because board games need at least two players to play. For example, in Tetris (a digital game), the player tries to overcome the previous score. In this case, the player competes with the timer. For example, in brain-training mini-games like Peak, the player always tries to gain maximum points in the time limit. It also overlaps with the competition with self because the player always tries to better their performance in the time limit.

Competition with an opponent. The player competes with another player. For example, snake and ladders, guess the fence, etc., in which each player plays their independent game without involving in the gameplay of the opposite team. But there will be a winning team who gains the maximum points in 'guess the fence' and the player completes the goal first in snakes and ladder. The competition is extrinsic outside the gameplay.

Competition in Educational games. Ideally, when competing with others, learners must work harder; as a result, all students improve their knowledge, allowing them to progress. Without competition, only the best of the class would improve their knowledge. Many studies have found positive effects of competition in GBL, such as enhanced motivation, a higher tendency to make risky plays, and decreased cognitive load (Admiraal, Huizenga and Akkerman, 2011) (Ercil, Ozcelik and Sahin, 2015). These positive effects may indirectly lead to the learning outcome and motivate players extrinsically to put forth more effort on gameplay but not through the game mechanics. One of the papers also mentioned that a game with no competition enhances knowledge better than the competition (Chen, Liu and Shou, 2018). It is so because players may emerge into competition and not concentrate on the content. The challenge based on competition always refers to time, i.e., who finishes first, external timer and playing for long without losing a life. Because competition refers to time, it is always an external element called exogenous mechanic.

3.2 Conflict

Conflict is any problem artificially created by the game designer between the players (Salen and Zimmerman, 2004). In single-player games, conflict is generated with non-player characters, and these conflicts are solved in the gameplay. So, it can be called an in-game element of challenge. In multi-player games, the conflict between the players is generated by common resources, having control over the opponent's game elements, etc. In conflict, the opponent's actions affect the player's gameplay and vice versa. As all these actions occur in gameplay, conflict is an intrinsic element and endogenous mechanism to generate challenge.

Conflict with self. The dilemma of making decisions in the gameplay is clearly observed in single-player games. For example, in Cross Words, the challenge is to form maximum words with the available alphabets. In Scrabble, also players try to form a word with the alphabets they get randomly.

Conflict with opponents. Here the opponent's skills will create the challenge. In this type of game, the opponent's actions will affect the gameplay. In the educational game 'Three Sticks', the player's knowledge regarding geometrical shapes will affect other opponent's gameplay.

Conflict with the game world. This type of conflict is mainly seen in role-playing games or single-player games. For example, Pac man, escaping from the enemies coming randomly from different directions is a challenge.

All the above conflicts are observed in the gameplay. So, conflict is an intrinsic challenge of the game.

Conflict in Educational Games. In the literature, no paper mentioned directly that conflict in the game enhances the learning but instead mentioned that challenging activity in the game enhances the learning outcome (Hamari et al., 2016). As conflict is an intrinsic element, it is an endogenous mechanic to generate the challenge, and it may positively affect learning outcomes (Malone and Lepper, 2021). The conflict in the game can be a special predictor of learning outcomes. Gameplay is nothing but solving the problem, and the player creates a problem for the opponent in a game based on conflict. Creating a problem requires more knowledge, which may positively affect learning outcome. More empirical studies are required in this area to understand the role of conflict in interaction, flow experience, and learning outcome.

Conflict is endogenous, and competition is the exogenous mechanic to generate the challenge (Malone and Lepper, 2021). Competition and conflict may both motivate the player to play the game. It can also be that one encourages the player more than the other. So, knowing which element of challenge enhances the learning outcome is essential. Competition and conflict are generally considered a mode of interaction with the game world or other players. But these modes of interaction are part of the challenge and can help to increase or decrease the difficulty of the challenge. According to the literature, there is one more interaction mechanic called cooperation. This kind of interaction is observed between the players in the games where they play together to achieve the goal. In cooperation-based games also, either conflict or competition or both is observed. In any team-based game, the challenge generates because of the team's abilities versus the opposite team's abilities. There is cooperation within the team and conflict between the teams.

4. Abilities

Abilities are required to achieve the winning condition or to face the challenge. Players need various abilities to play games like Physical abilities, Intellectual abilities. The player requires knowledge and other skills when it comes to educational games. The game designers create challenges based on at least one of these abilities. Challenges based on more than one ability will be more effective.

4.1 Physical abilities

Field games are the best examples to explain physical skills. The field game requires physical skills specific to the game, so the skills of the opponent team decide the level of challenge in the game. The board game carrom is a good example of a mix of physical skill and thinking, but physical skills dominate the game. It depends heavily on the control over force executed by the finger. However, these physical actions in the game are from the player's taught process, but it has to be accomplished through the player's physical skills. Any digital racing games or other games that require speed or shooting require motor skills. The player should be able to move from one key to another quickly.

In the case of educational games, these motor and physical skills can be used to train the players. Simulation games like landing flights or driving use motor skills to train players. In the case of learning academic content or acquiring knowledge, the game mechanics dominated by motor skills will train the player in a particular skill but not in acquiring knowledge. It is not endogenous if the player is running for some correct answer and the competition or rewards are based on who runs first, nothing to do with learning. Here the competition might externally motivate the player to play but does not contribute to the learning outcome. The player emerges more into running than acquiring knowledge.

4.2 Intellectual abilities

Some of the games involve the ability that is thinking or strategizing. A simple example that is based on strategizing is knots and crosses. It focuses mainly on problem-solving abilities, and the opponent creates the conflict. The opponent's skill of visualisation and strategy is a challenge to the player. The game mechanics based on strategy generates conflict between the players rather than competition. Competition can be generated externally by including a timer or by competing to finish first. So, in strategy-based games, competition is the external element of challenge. The games based on thinking and strategizing can be used to train problem-solving skills. In learning academic content, this skill can help to gain learning outcome if strategizing is based on knowledge of the content.

Memory: In the game 'Match the pair' all the cards are laid face down. Players have to make a pair of similar cards by flipping the cards. It forces the player to recall where the required pair card is located. Because the playing cards are laid down face down randomly, there is an element of chance that all players experience. But the dominant ability in the game is memory. In educational games, if the conflict is based on memory, it will help to acquire knowledge. This ability can be used in games based on academic content like factual knowledge, for example, vocabulary.

4.3 Knowledge

Knowledge is an important ability in educational games. Using knowledge as a requirement to complete a challenge helps to enhance the learning outcome. For example, Scrabble primarily relies on knowledge and memory of words and spellings. The challenge is to build words from the set of alphabets. Because the alphabets are selected blindly from the pouch, there is also a small component of chance. Clearly, the three variables, knowledge, thinking, and chance, are playing a role in that order with no contradiction with each other. But it gives an advantage to players with 'knowledge' of words. So, the dominant variable is knowledge.

4.3.1 Prior Knowledge

In terms of gameplay, it is known that how the in-game performance of learners varies with different levels of prior knowledge. Few studies also tested with simulation games that players having prior knowledge perform well in educational games than players with less prior knowledge (Yeonjoo *et al.*, 2019) (Dong, Jong and King, 2020). The players with prior knowledge follow a systematic approach towards the gameplay with better speed, accuracy, and a less cognitive load than players with less prior knowledge or no prior knowledge.

But here the question comes, is it important to have prior knowledge to play educational games? This can be answered using flow theory for games. The prior knowledge and challenge are dependent on each other. If there is no prior knowledge and the challenge requires knowledge to play, it leads to anxiety. The player does not feel challenged if the prior knowledge is high. But the other necessary abilities in the game can engage the player to practice because the gameplay is different every time you play a game.

In terms of learning, it is largely unknown how the learning outcome of the players varies with different levels of prior knowledge. It will be interesting to see the learning outcome of players with prior knowledge and no prior knowledge. The ideal learning curve can explain this concept.

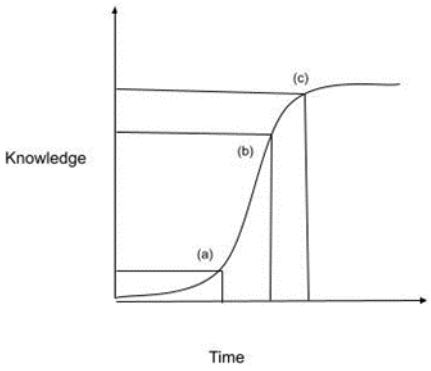


Figure 3: Learning curve in educational games

If the player has no prior knowledge about the concept that the game is trying to make the players learn, then reaching a point (a) in the above figure takes a lot of time (multiple plays). The knowledge acquisition is very slow if the player has no prior knowledge. If the player already has the knowledge till point (a) before, the player takes significantly less time or number of plays to reach point (b) because the game helps to build their knowledge based on prior knowledge. If the player has prior knowledge, we observe the significant difference in knowledge gained with one or two plays. If the player has complete knowledge till point (c) on the topic based on which the educational game was made, then there might not be knowledge gained from the game, but it can be used for practice. Other game elements can engage the player and motivate the player to play the game.

Other abilities and chance in the game can engage the players and motivate them to play the game, but knowledge enhances learning. Games that include conflict with knowledge make the game endogenous. If the player is improving his gameplay, and this improvement can be referred to as learning the content, then it is called an endogenous game. If the game involves other abilities without knowledge and asks questions between the gameplay like a quiz, then it is an exogenous game. Exogenous games can create a game environment and fun but will not enhance learning. Combining knowledge with other skills can make games both endogenous and engaging.

5. Chance

In games like Snakes and Ladders and Tambola, all the actions taken place in the game are governed by a random number. In Snakes and Ladders, all the actions are governed by the number that is generated by the dice. In the game Tambola, a person is assigned to take one number at a time from the bowl, and the player who makes the first row or column will gain points, and the full house will be the winners. So, all the actions are governed by a person who picks a number randomly. Chane has nothing to do with the player's skill. The player cannot manipulate their gameplay through their abilities. Instead, the external element of the gameplay will manipulate the player’s gameplay.

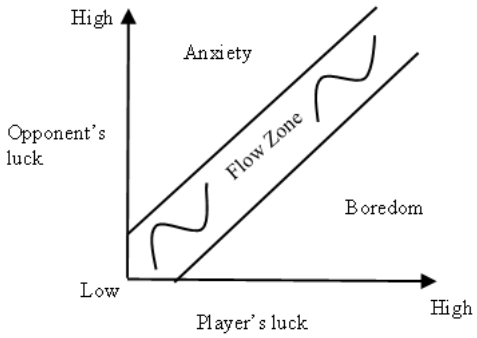


Figure 4: Flow in chance-based games

According to flow theory, in chance-based games, it is player's luck versus opponent's luck. The opponent's luck is the challenge for the player. If the opponent's luck is greater than the player's luck, it leads to anxiety and if the player's luck is greater than the opponent's luck, it may lead to boredom. The uncertainty is high in the games based on chance because no skill is involved. In complete chance-based games, there is no conflict between the players. It has only competition between the players. To experience the flow state, the major component of the flow "sense of control" is important. This can be achieved by adding one of the abilities to the chance. For example, Ludo has both luck and strategy/thinking skills. Even though luck dominates the game, the player will feel a sense of control over his actions. In the case of educational games, if the competition is based on luck and knowledge, then there will be uncertainty in the game, and it also leads to learning outcome if the dominant skill is knowledge. Knowledge will create a sense of control to experience a flow state.

6. Conclusion

According to flow theory, challenge and abilities are the important variables in experiencing a flow state during the gameplay. Completing the activity in the game with some limitations is a challenge in the case of single-player games. In the case of multi-player games, the abilities of the opponent players are the challenge. Based on flow theory, competition and conflict are two mechanisms to generate challenge. Most of the games have both competition and conflict to build challenges. Competition can motivate the player to play games, but conflict helps in enhancing learning through games because it is an endogenous mechanic. The challenges in the game require different abilities like physical, intellectual, and knowledge to play. Chance is another necessary element in games based on chance, but it is not an ability. These three abilities and chance can achieve all the challenges in the games. Chance with the combination of any of the abilities will create the feeling of ease of control which is important for the flow experience.

In the case of educational games, knowledge as an ability plays an essential role in enhancing learning. Other skills can make the game engaging and interesting, but knowledge helps the player to build understanding based on prior knowledge. If the game has a conflict as a challenge and knowledge as the ability to complete the challenge, it makes the game endogenous and enhances the learning outcome. More empirical studies are required in this area to build a correlation between the conflict and learning outcome.

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Automatic Calibration for a Mutual Insurance System in a Multi-Player Serious Game

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Abstract: In the context of a serious educational game that motivates children to adopt more sustainable home-to-school mobility habits, we designed and implemented a collaborative multi-player mutual insurance system, with the intent to support low-performing players with the help of high-performing ones. As a preliminary step towards a field study evaluating this new game mechanic, in this paper we present the design and the development for an automatic calibration of the system, simulating the effects of the choices for each parameter in the player's game progression.

Keywords: Serious games, Playful education, Design methods, Gamification in education

1. Introduction

Serious games can be defined as "games in which education, in its various forms, is the primary goal, rather than entertainment" (R. Michael & L. Chen, 2006).

Serious games are routinely applied for learning, education, and training, and this research topic has been rapidly growing over the last years (Hooshyar et al. 2018, Jagušt et al. 2018, Kickmeier-Rust et al. 2014, Marconi et al. 2018, Ferron et al. 2019). In particular, Games-Based Learning (GBL) helps students develop skills and knowledge and strengthens their ability to handle the learning experiences provided by the games. (Al-Azawi et al, 2016).

In all games with a purpose, keeping the player engaged for longer may result in a more permanent and significant behavior change, and thus player retention becomes particularly relevant (Berkovsky et al. 2010, Vassileva 2012, Kaptein et al. 2012, Jacobs 2016).

For this purpose, it is paramount to design the game adaptivity and personalization (Streicher & Smeddinck, 2016): that is, being able to adjust the content and interaction schemes of games, as virtual environments, to the knowledge level, skill, preferences, and experience of the users.

Recent studies conducted on the effects of serious games show that also in this domain, personalization and adaptivity can promote user acceptance, motivation, and retention (Hooshyar et al. 2018, Jagušt et al. 2018, Kickmeier-Rust et al. 2014, Legaki et al. 2019, Monterrat et al. 2017, Stuart, Serna, Marty, Lavoué & Lavoué 2019, Orji, Nacke & Di Marco 2017, Orji, Mandryk & Vassileva 2017, Scanagatta et al. 2020).

This paper focuses on KidsGoGreen, a serious game that motivates children to perform daily trips from home to school in a sustainable way. Teachers can define personalized virtual journeys across the world and associate to each stop multimedia educational material. The sustainable km performed by each pupil through home-to-school trips contributes to the advancement of the whole group in the virtual journey. The educational material is unlocked when the group reaches each stop. In this manner, the entire school community (children, teachers, and families) is involved in a collective playful educational experience.

The KidsGoGreen experimentation in schools highlighted the need for continuous monitoring and re-calibration of the game during operation. The teachers program each stage in the team's route to be reached in a specific time frame, yet a high variance might affect the performance of the children.

For this reason, a class could miss the deadline by several days, which could be particularly problematic for a mid-game stage set before the Christmas holiday season or the final stage set before the end of the school year. The factors responsible for the performance variance might be external (weather, road conditions) or internal (class overall motivation and dedication, school schedule).

To reduce this variance, we designed a multi-player mutual insurance system. A high-performing team (class of pupils) can donate the excess gained game points (virtual km) to a shared mutual fund. On the other hand, a low-performing team can withdraw from the mutual fund the game points required to reach the next stage.

As a preliminary step towards a field study evaluating this new game mechanic, it was necessary to calibrate its inside workings carefully. After we obtained real-world data from the previous iteration of the serious game, we designed a simulation procedure. We then evaluated different approaches and the values of the different parameters governing the mutual insurance system to analyze the effects on the game progression.

Furthermore, with the introduction of this shared fund, we also introduced in the KidsGoGreen game basic economics principles such as *inflation* and *deflation* to keep the overall system in equilibrium. This exploration constitutes (as far as we know) the first exploration of this research topic.

In Section 2 we first present relevant work in the literature. In Section 3 we detail the context of the gamified system. In Section 4 we explain the details of the multi-player mutual insurance system. In Section 5 we discuss the insights we gained from its simulation and tuning. Section 6 concludes our paper.

2. Literature review

Serious games have proven successful in raising awareness, increasing participation, and promoting sustainable behavior in social, environmental, and health domains (Seaborn & Fels 2015, Deterding et al. 2011, Bielik et al. 2012, Ferron et al. 2019).

However, game content adaptivity and personalization in a multiplayer setting, particularly relevant for non-competitive and collaborative games, is a well-recognized and still uninvestigated problem (Streicher & Smeddinck, 2016).

In the presence of several players with very heterogeneous performances and preferences, adaptive algorithms need to properly calibrate the game to meet their expectations and skills (Stuart, Serna, Marty & Lavoué 2019).

Moreover, if not carefully designed and properly implemented, automatic game adjustment can have a substantial impact on the balancing and the perception of the balancing by the players, which may interfere with their game experience.

It is essential to render the game adaptation transparent to players. In Gerling et al. (2014), the authors compare visible and transparent adjustment strategies in an established motion-based game.

The study revealed that explicitly observable calibrations might negatively impact players' self-esteem and feelings of relatedness in player pairs. In contrast, transparent adjustments seemed to improve self-esteem and reduce performance differences without affecting the player experience.

As a recent example, in Scanagatta et al. (2020), the authors committed to promoting a more even player experience across players without overly rewarding high-performing ones or penalizing low-performance ones. The study focused on an educational game targeting primary school children whose goal was to raise their awareness towards the reduction and correct disposal of e-waste. In this work, the modification of the game mechanics was *transparent*, as the children were not made aware of its existence and did not discover it during the game's execution.

Mutual insurance is a well-known concept (Cass et al. 1996, N. O'sullivan 1998). Its goal can be defined as "*to provide its members with insurance coverage at or near cost*".



Figure 1: Virtual journey in KidsGoGreen, programmed by the teachers for the school year. The educational material associated with each stop is unlocked when the whole class collects enough real-world kilometres travelled with a sustainable mode of transportation

While mutual funds hold a strong position in the market, they and the implications of the organisational form have attracted limited interest among academics (Talonen 2016). Our purpose is to help in this matter, with regards to their application to the context of educational games.

3. Application context

KidsGoGreen is an educational game that targets primary and secondary schools, and aims to induce a collective shift towards sustainable home-to-school mobility habits. It involves the entire school community (children, teachers, and families) in a playful educational experience based on a virtual educational journey around real-world stops.

3.1 KidsGoGreen experimentations

KidsGoGreen has been deployed in primary and secondary schools in various Italian regions for several years. During 2020-2021, 62 KidsGoGreen virtual journeys were activated in 54 schools, involving more than 3,000 students.

These experiments showed an impact on home-to-school mobility that exceeded all expectations: a 56% percent reduction in car trips to school.

The system has also shown a high educational and didactic value. Teachers and school managers testify how KidsGoGreen has been for them "a completely new way of teaching", which has enabled interdisciplinary and inclusive paths, intra- and inter-class collaboration, and enthusiastic participation of teachers and students.

Families also see a significant impact of KidsGoGreen in terms of children's awareness of environmental sustainability issues and autonomy in home-school trips and during free time.

3.2 KidsGoGreen current limitations

In the post-game evaluation, some pupils and teachers reported their frustration when proceeding too slowly in the virtual journey. Others report that they were proceeding too fast, that the unlocking of some stops was too frequent, and that they did not have enough time to use and elaborate the associated educational material properly.

This comments, in general, regards the broad issue of calibration. At the moment, it is performed with the following steps: The game's duration is decided in advance (typically from 2 months to the whole school year). Then it is necessary to decide the number of journey's legs, and their distance (the amount of virtual kilometres needed to unlock them).

Teachers have to make an educated guess on the estimated whole class *travel speed,* based on the current home-school mobility habits of the children, and an estimation of their possible behavioural improvement.

Firstly, the initial calibration might be optimistic or pessimistic, leading to a growing distance between the game's supposed execution, and the observed team's performance.

Furthermore, during the game operation, the children's performances may vary, due to external factors (weather, road conditions) or internal (class overall motivation and dedication, school schedule).

As depicted in Figure 2, for each KidsGoGreen stop, we can think of a window of arrival. Given the target (dotted blue line) and the estimated daily speed (gray line), it is possible to estimate the arrival date (blue vertical line). The sustainable km performed each day by the group of students may vary (red line).

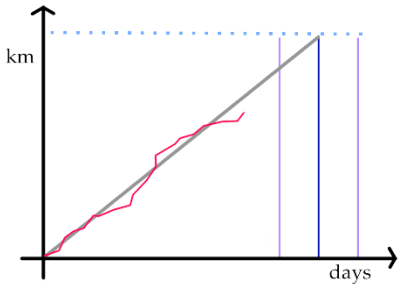


Figure 2: Example of maximum allowed delay / advance of a game

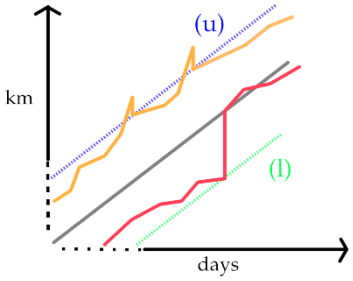


Figure 3: Example of *bounded performance*

While a deviation from the expected arrival date is acceptable (violet lines), significant delays or advances in the game can compromise the overall experience.

The system does provide tools for monitoring (i.e., reporting significant deviations from the estimated daily group speed) and re-calibration (i.e., assignment of group-level challenges to make up for delay). However, the workload required on the teachers to correctly use these tools was found to be excessive.

4. The KidsGoGreen Mutual Insurance System

We thus introduce in the game a new game mechanic, as defined in the MDA framework (Hunicke et al., 2004): the *mutual fund*, a game point concept shared by all the teams.

When a team obtains a number of game points (the virtual kilometres gained through sustainable home-to-school trips) higher than a given threshold, the points in excess are *donated* to the fund.

Vice-versa, when a team falls behind a given threshold with its game points, the required points are *withdrawn* from the fund (given the condition that the fund contains a sufficient residual amount).

This behavior is similar to a basic insurance fund, where the team's deposits are the premiums, and the team's withdraws are the claims. Attention must be given to the evolution of the mutual fund amount. A significant difference in the team's deposits and withdraws leads to either over-performing or under-performing behavior.

This generates a *bounded performance,* as shown in Figure 3. Blue dotted line is the upper bound (deposit threshold); green dotted line is lower bound (withdraw threshold). The orange line is a team's performance that exceeds the maximum allowed advance; the red line instead exceeds the maximum allowed delay. The two parameters can be thought of as "what is the maximum advance/delay allowed to teams in the game?", creating a "channel" for containing the team's performance.

Finding the equilibrium between "premiums" and "claims" is the main goal of insurance research; in this particular application context, we must face the critical limitation that it is impossible to gather sufficient data to predict the team's performances with a sufficient degree of precision.

We decided to circumvent this problem by introducing a parameter with which it is possible to affect the economic behavior of the system directly. When a team donates game points to the system, the amount is

multiplied with a given factor before being added to the fund. With a value of the factor higher than 1, this corresponds to a process of *inflation*. Vice-versa, with a value lower than 1, this corresponds to *deflation*.

We note that the particular game context has characteristics that make it suitable for "behind the scenes" adjustment. Firstly, its primary target is children; previous exploratory work in this area showed that they do not perceive such game manipulations (Scanagatta et al., 2020). They are *transparent*, and thus appropriate for reducing performance differences without affecting the player experience (Gerling et al., 2014). Secondly, the game does not feature a competitive aspect, and the narrative is suitable to favor a collaborative aspect (helping each other to reach their journey's destinations).

Therefore, we have identified three parameters that control the execution of the multi-player mutual insurance system: the *deposit-threshold*, the *withdraw-threshold*, and the *economic-adjustment*. The value given to these parameters and how they are handled can radically change the game's course. The next section will show the insights we gained from their calibration.

5. System Simulation & Evaluation

As a preliminary step for a field study, we created a simulation apparatus that could help us understand how different strategies and values for the system's parameters would affect the team's experience.

5.1 Evaluation indicators

To compare different strategies for the parameters' calibration, it was necessary to define the *objective function*: the set of goals that could allow evaluating each combination. First, we identified the two main fundamental indicators of the overall mutual insurance system's goals.

The first was the mean teams' delay (computed regarding their *expected performance*), which indicated the mean number of days a team would need to continue playing to reach the end of their virtual journey.

The second was the total number of withdraws. From the point of view of a children's team, each withdraw represents an event in the game where their under-performance is compensated through the mutual fund. Limiting the number of withdraws is of utmost importance to maintain the team's motivation high - withdraws need to be perceived as exceptional events in the game.

The same cannot be said of deposits, which represent a positive event in the game in which the team, having accumulated more game points than expected, donates the excess to the mutual fund.

The mean teams' delay and the total number of withdraws indicators are directly linked. In the proposed mutual insurance system, the withdraw mechanic is the primary means to alleviate the teams' delay. Thus the two parameters have to be taken into consideration simultaneously.

5.2 Simulation

We now define the simulation procedure we implemented. The basic concept is to choose one combination of parameters' values, simulate the execution of many games, and collect precise statistics on the overall game's progress. Comparing those statistics allows us to understand better the effect of choosing different strategies and values for the parameters.

First, we collected performance from the previous executions of KidsGoGreen, obtaining data from 69 real-world classes. In each simulation, we randomly choose 40 of them.

From each real-world data, we defined a synthetic team, randomly choosing the start date of its game (in a period ranging across 365 days). The corresponding real-world data sampled its journey goals, performances, and journey duration.

For each day of the simulation (lasting a year), we then simulated the performance of each synthetic team. We then computed the *expected performance* (based on the target of the next leg of the journey, and the number of remaining days), the *deposit-threshold* and the *withdraw-threshold* (based on the expected performance and the different approaches that we will outline in the following subsection). We followed these guidelines:

1. If the synthetic team's game points total was higher than the *deposit-threshold* at the end of the day, all the game-points over that threshold were removed from the team's points pool, multiplied by the *economic-adjustment* parameter, and added to the shared mutual game points fund.
2. If instead at the end of the day the synthetic team's game points total was lower than the *withdraw-threshold*, an amount of game points equal to the difference between the *withdraw-threshold* and the *expected performance* were removed from the mutual fund, and this difference was added to the team's points pool.

Notice: The withdrawal was executed on the condition that the mutual fund had a residual amount higher than the required amount - the mutual fund was not allowed to be overdrawn.

5.3 Economic Adjustment

We now analyze the parameter of *economic-adjustment*, which regulates the inflation/deflation economic behavior of the mutual insurance system. At the start of our research, we treated it as an independent parameter like the others. We then realized that we could instead treat it as a *dependent* parameter, thus removing the need to calibrate it independently, reducing the search space of the parameter calibration of one dimension.

The reason is that it refers to a mechanic that is by design *transparent*; if the change on the raw numbers is performed in such a way that the players are made not aware of it, then the actual value governing the change is not relevant (apart from being constrained inside some reasonable hard-limits).

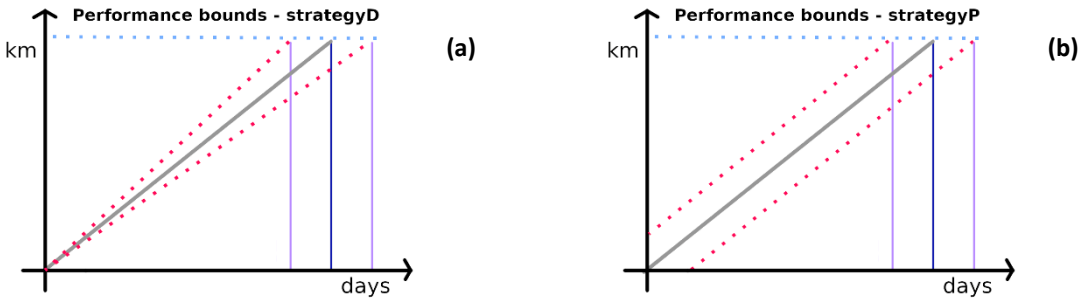


Figure 4: Representation of the approach for *deposit-threshold* and *withdraw-threshold* (red dotted lines) as a percentage of the player's performance, for either strategyD (a) and strategyP (b)

The *economic-adjustment* affects the fund size directly, since each deposit by the teams is multiplied by its value. Consequently, it affects the withdrawal rate, as the fund is not allowed to be overdrawn.

Keeping in mind those considerations, we then produced a procedure to define the parameter's value. The parameter *economic-adjustment* was set to the starting value of 0.6. A first simulation was performed in which the total number of withdraws was noted.

The value of the parameter was then increased of 0.2. A new simulation was performed, and again the total number of withdraws was noted, and compared with the moving average of the last ones recorded. If higher, the new value for *economic-adjustment* was confirmed, and the loop continued. Otherwise, the calibration ended.

5.4 Deposit and Withdraw threshold

We now describe how we calibrated the *deposit-threshold* and the *withdraw-threshold* parameters, which govern the corresponding mechanics. For the calibration of those parameters, we tested two strategies.

The first is to define them as a percentage of the team's performance. For example, we tested the set of values (1.10, 1.05, 1) for the *deposit-threshold* and (0.95, 0.9, 0.85) for the *withdraw-threshold*. This approach corresponds to defining upper and lower bounds divergent from the performance line. We gave this approach the name of strategyD. We present a visual explanation in Figure 4a.

The second strategy is to define the threshold as a percentage of the expected team's total performance. For example, we tested the set of (0.1, 0.2, 0.3, 0.4, 0.5) for both the parameters - to be added or removed to the

current expected team's performance. This approach corresponds to defining upper and lower bounds parallel to the expected performance line. We gave this approach the name of strategyP. We present a visual explanation in Figure 4b.

We observed the effect of the two strategies on the two indicators that have been chosen as evaluation criteria. About the total number of withdraws, we recognized that its distribution in the majority of the simulations performed with the first strategy was heavily skewed. This was because the bounds are very close at the start of the game, and it is thus frequent for the team's performance to fall out. We provide an example in Figure 5a. Across all the simulations, the mean of the medians of the distribution was 7.48.

Instead, with the second approach, we observed that the distribution of teams' withdraws was more evenly distributed during the game's duration, thus solving the problem outlined before. We provide an example in Figure 5b. Across all the simulations, the mean of the medians of the distribution was 31.26. However, we also recorded a very high variance in the team's statistics. We found that journeys length distribution also showed a high variance; thus, this disparity influenced the parameter's effect, as it was directly involved in their calculation.

To solve this problem, we thought to define the threshold of the parameters using as a unit of measurement the number of days (based on the team's expected daily performance) - meaning that the deposit threshold indicated now the maximum allowed number of days of advance on the expected journey's end (for the withdraw threshold, it indicated the maximum delay). The values tested were (1, 2, 3, 4, 5, 6, 7) for both parameters.

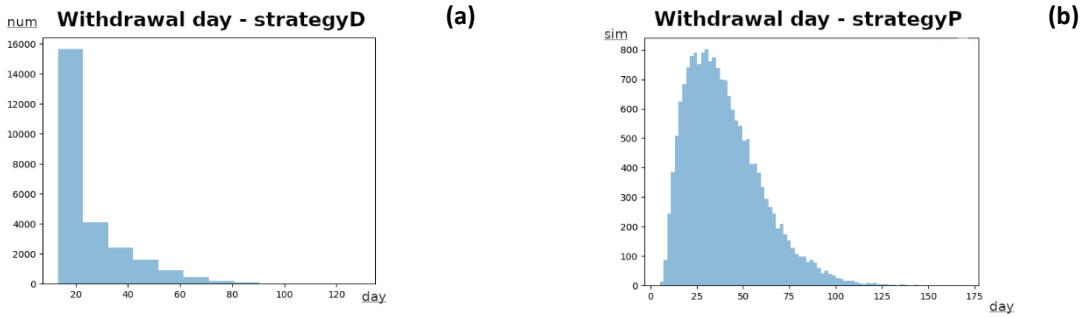


Figure 5: Example of the distribution of the game day on which withdraws have been performed, for either strategyD (a) and strategyP (b)

5.5 Insights

We now present the main insights we gained from the simulations.

To show the different effects of changing the value of one parameter with respect to the other, we produced *pivot* graphs: meaning that the value of one parameter was fixed, and we superimposed the distributions obtained by all the possible values of the other parameter.

We will present the graphs pivoting on only one value for both parameters to have a meaningful exposition. To this end, we choose the value of 4 as a middle ground. We report that the graphs' upcoming remarks were also observed pivoting over other values.

We start with pivoting *deposit-threshold*. In the following paragraphs, we will show the observed effects of varying the value for *withdraw-threshold* from 1 to 7.

As the threshold increases in value, the total number of withdraws becomes more skewed to the lower values on the left - meaning that fewer withdraws are performed in general. This behavior is reasonable, as a high value for the parameter indicates a farther bound which activates the withdraw, decreasing their frequency. We report this in Figure 6a.

As the threshold increases in value, the distribution for the withdrawal's game execution day exhibits a lower kurtosis but a similar skewness. The explanation for the first finding is a direct consequence of the previous point, as there are a lower number of withdraws in general. We report this in Figure 6b.

As the threshold increases in value, the mean teams' delay distribution shows both a higher skewness and a higher kurtosis. It is interesting also to observe a sharp decline of the distributions close to the threshold value, with nonetheless a small tail representing the cases in which teams who fell behind the threshold could not activate the threshold due to the mutual fund having insufficient capital. This could be improved by manually increasing the *economic-adjustment* parameter. We report this in Figure 6c.

We now proceed with pivoting on *withdraw-threshold* and showing the effects of varying the value for *deposit-threshold* from 1 to 7.

As the threshold increases in value, the distribution of the total number of deposits shows a higher skewness to the left, meaning that fewer deposits are performed in general. This behavior is reasonable, as moving away from the threshold makes reaching it less frequent. We report this in Figure 7a.

As the threshold increases in value, the deposits' game-day execution distribution shows a lower kurtosis and a similar skewness (similar to what was observed with the withdraws). We report this in Figure 7b.

As the threshold decreases in value, the number of withdraws decreases, as a bound for this parameter too strict will prevent teams from ever being in advance, and thus more at risk in the future of falling behind. We report this in Figure 7c.

Finally, in Figure 8, we report the values for the parameter economic-adjustment, automatically computed from the other two parameters. We first observe that the value for *economic-adjustment* was always higher than 1. In all cases, an inflation mechanism was needed to keep the mutual fund in equilibrium. We then observe that low values of *withdraw-threshold* (WT, on the x-axis) and *deposit-threshold* (DT, on the y-axis) lead to low value of *economic-adjustment*. This behaviour can be explained by the fact that low inflation is sufficient when there are frequent deposits and withdrawals. Instead, the calibration needs high inflation when deposits and withdraws are rarer (high values for WT and DT - meaning further correction bound).

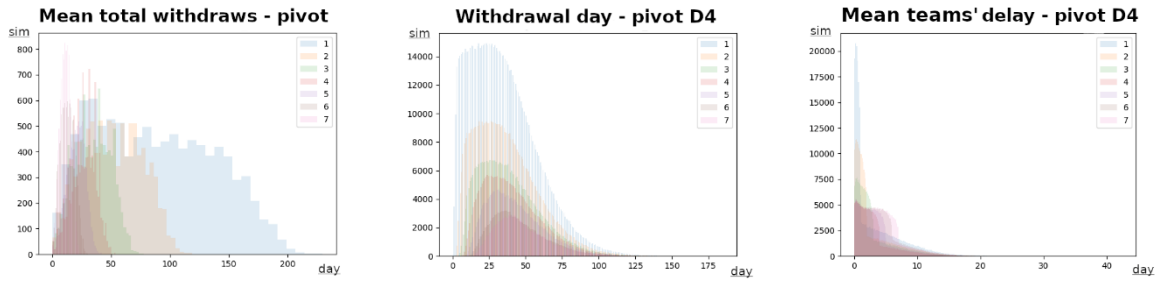
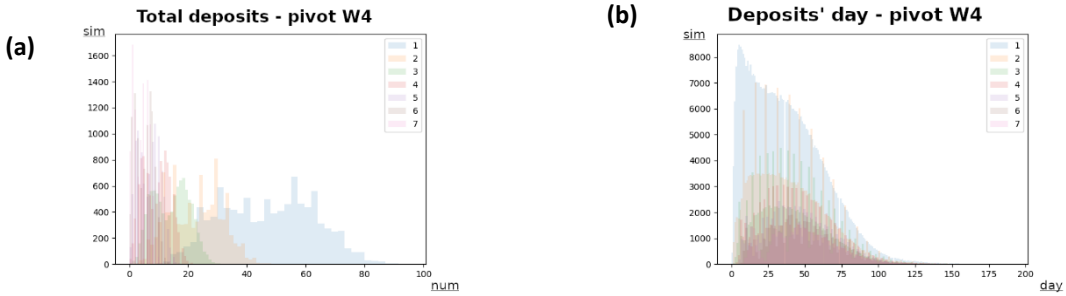


Figure 6: Distributions for withdrawal's mean total number (a), withdrawal's game execution day (b), mean teams' delay (c). Pivot on *deposit-threshold* = 4



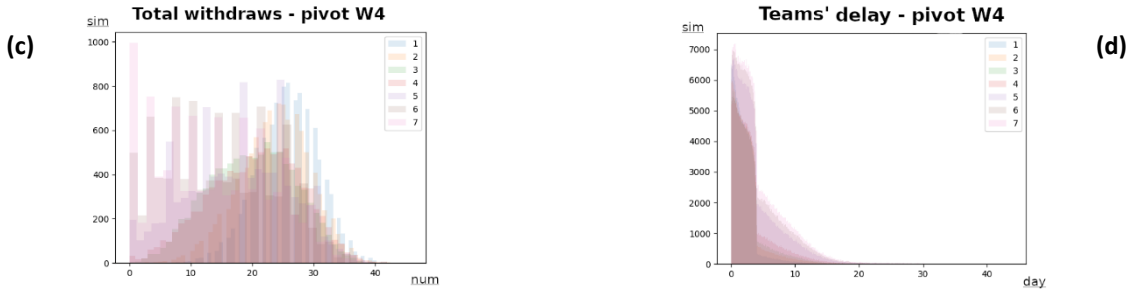


Figure 7: Distributions for the deposits' total (a), deposits' day (b), withdraws' total (c), teams' delay (d). Pivot on *withdraw-threshold = 4*

6. Conclusion & Future Works

This paper presented the design, the development and the initial calibration of a mutual insurance system for a multi-player sustainable mobility educational game.

As a future work, we will conduct a field study for the evaluation of this new game mechanic. In particular, we will (i) investigate whether and how it affects students' motivation towards the goal of promoting sustainable home-to-school mobility habits; (ii) analyze its efficacy in terms of reduction of the variance of the teams' progression; (iii) evaluate its impact in terms of educational value as a mean to introduce and reflect in-class about the key concepts and principles of mutualism and cooperation in general.

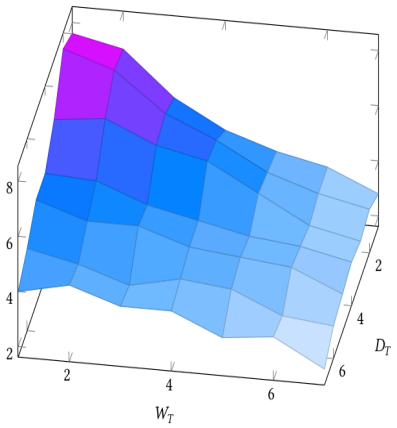


Figure 8: Distribution of the values for the parameter *economic-adjustment*, automatically computed from the values of *withdraw-threshold* (W_T, on the x-axis) and *deposit-threshold* (D_T, on the y-axis)

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How to Evaluate Serious Games Concepts? A Systematic Prototyping and Testing Approach

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Abstract: The challenge in developing a serious game is to find the perfect balance between learning and playing. The development process should include an appropriate involvement of the target group and enable a systematic evaluation of this balance through prototyping and testing. The goal is to create an entertaining and purposeful learning experience and thus enable knowledge growth. This paper presents the evaluation results of the serious game E.F.A. with the target group – managers in the social service sector. The first prototype was tested in an early phase as a paper prototype by experts in media didactics and subject experts. Early stage testing is a decisive factor for the development of serious games. However, the accessibility of the target group is not always given for fast testing and iterative improvement. After collecting expert feedback and incorporating it into the game, the high-fidelity prototype was created and tested by the target group. Those test runs were followed by group interviews. Their results are the focus of this paper which aims at answering the following research questions: How did the target group experience the serious game and their increase in knowledge? To what extent can the evaluation results with the target group be linked to the early tests with the paper prototype? How does the feedback vary and what conclusions can be drawn from this? The results of the paper show that the serious game was rated very differently among the target group. Some generally praised the playful approach. Others criticized the game as childish and unsuitable for the target group. The feedback obtained from different user groups with the help of different prototypes varied for a set of evaluation criteria such as playing time, remembered knowledge and dialogs. For each evaluation criteria recommendations are given regarding the test group and type of prototype.

Keywords: serious games, evaluation, user-oriented, learning experience design, prototyping

1. Prototyping and testing during the development of the serious game E.F.A

When developing serious games, a balance between learning and entertainment must be established. This means achieving the intended learning objectives while creating enjoyable experiences (Marr 2010, Lampert et al. 2009). This can increase the motivation of the learners (Egenfeldt-Nielsen 2005). Within ideation, prototyping and testing phases of serious games different professional perspectives need to be combined. The concept of learning experience design (LXD) takes up this interdisciplinary approach. The main focus of LXD is to create “more engaging, innovative and effective experiences for learners in different environments” (Ahn 2018, p. 1). This young design discipline combines specific design knowledge and methods (from interaction design, user experience design, human-centered design, etc.) with experience from the field of methodological-didactic design of learning experiences and from IT/software development, among others (Kircher et al. 2021). The increasing collaboration between different disciplines as well as the rising costs for creating digital learning materials like serious games, require a refinement and optimization of development processes. It is becoming more important that solutions are developed and tested as early and effectively as possible so a large part of the resources can go into creating the final design (Cennamo, Kalk 2019). For that, the target group should be involved as early as possible to ensure that the game meets their needs. This can be achieved by testing the game concept using prototypes during the development process to obtain feedback from the user group (Ampatzidou and Gugerell 2019, Sailer 2016).

In order to examine the development process of serious games this paper focuses on the project E.F.A. which aims at developing a serious game for the purpose of improving occupational safety and health (OSH) and its implementation, especially in small enterprises. The player takes on the role of an expert in OSH and runs through four temples in the "obligation jungle". The most important aspects of OSH are imparted through various learning tasks (mini-games) and a knowledge repository. Inserted dialogues convey the game story.

During the development of the serious game E.F.A. a systematic approach was applied in which phases of prototyping and concept development alternated with test phases (see figure 1). As soon as the first didactic concept was available a prototype was developed that enabled the testing of the game.

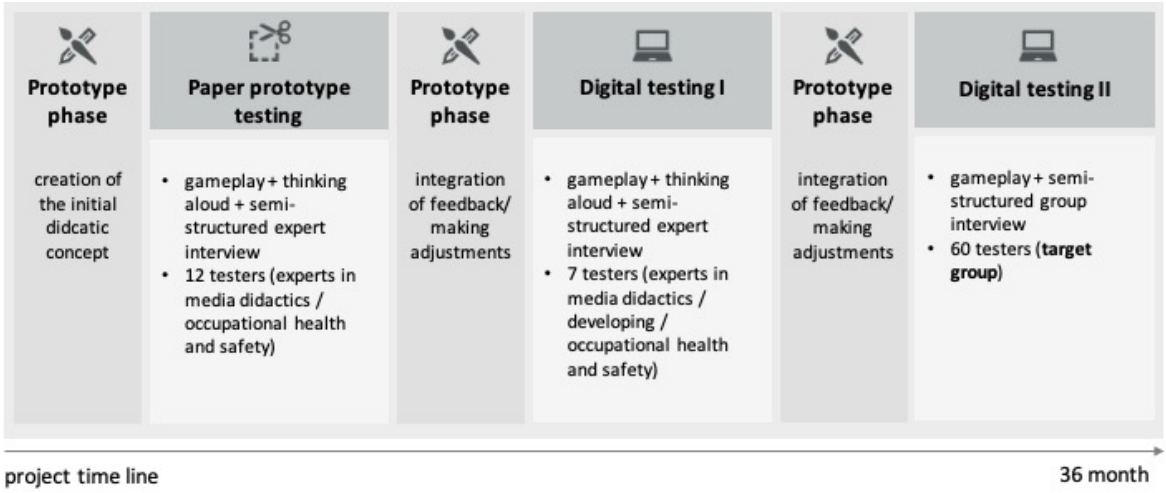


Figure 1: Systematic prototyping and testing scheme for the serious game E.F.A

A distinction can be made between low and high fidelity prototypes. A detailed overview of the classification of fidelity dimensions can be found in Zdralek (2000). Low-fidelity prototypes are used to quickly and without great cost generate feedback for an idea in early development phases (Abidin et al. 2019, Giacomelli et al. 2018). Paper prototypes are a specific form of low-fidelity prototypes. They can be described as "a variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person “playing computer” [...]" (Snyder 2003, p. 4). They are also used in game development where they function as a kind of board game. The logic and game mechanics are often similar to those of the digital game that is going to be developed (Schell 2016). High-fidelity prototypes are already very close to the final product and more technically sophisticated. However, they require much more time and resources (Zhang et al. 2012). There is still disagreement in the scientific discourse about the effective use, limitations and validity of various forms of prototypes during different stages of development (e.g. Wiklund et al. 1992, Zhang et al. 2012, Sauer and Sonderegger 2009, Sefelin et al. 2003, Walker et al. 2002, Virzi et al. 1996). But it seems clear that "effective and efficient evaluation methods and measurements are essential to the success of the iterative design process" (Zhang et al. 2012, p. 2).

By implementing a test phase in the E.F.A. project at an early stage, the game concept could be comprehensively evaluated with the simplest possible means before it was transferred to a digital version. Therefore, the overall prototyping and testing scheme used different forms of prototypes with different levels of fidelity. In a first phase the paper prototype was extensively tested with experts from various disciplines. The expert feedback was incorporated into the didactic concept and the first digitally playable prototype was created. This was again tested with different expert groups. A comparison of these two test phases already showed that the paper prototype was a useful instrument for testing basic elements of a serious game, such as the complexity and suitability of the learning tasks. In order to test more specific elements and the usability the digitally implemented version was more suitable (Stagge and Schade 2021). After the first two test phases were completed, the digital prototype was finalized and tested with the actual target group.

An efficient and effective development process involves not only choosing the right prototype at the right time, but also paying attention to the actual test participants and the type of feedback they can generate. For early tests with rather immature prototypes, it is advantageous to choose a test group with good access from which benevolent feedback can be expected. Once the prototype has been further developed, test persons who are more distant from the development team and who are not familiar with the prototype should be involved (Kapp et al. 2013). E.F.A. was designed for the target group of the social services sector. This includes hard-to-reach groups, such as nursing. Therefore, the full implementation of a user-centered design process was a great challenge. At the beginning of the project the target group and the context of use were analyzed comprehensively. For the early testing, the team mainly relied on experts from different disciplines, as they were easily accessible and thus a fast cycle of testing and adapting could be established. This approach raised the question of the extent to which early prototypes for serious games can also be tested by a wider circle of experts and still result in a product that is considered useful by the target group.

2. Research Questions

This paper addresses the following research questions:

- How did the target group experience the serious game and their increase in knowledge?
- To what extent can the evaluation results with the target group be linked to the early tests with the paper prototype? How does the feedback vary and what conclusions can be drawn from this?

By answering these two research questions, the paper reveals how E.F.A. was perceived and evaluated by the target group regarding a pre-defined set of evaluation criteria (section 3). These results paired with the already described systematic testing scheme (section 1) provide practical insights that can be used by future designers of serious games.

3. Methodology

An iterative testing approach was used in the evaluation of E.F.A.. The first draft of a didactic concept resulted in a paper prototype, which was modified after each test run according to the given feedback. The digital prototype was also first tested with experts (see comparison of both test runs in Stagge and Schade 2021) before being evaluated with the target group. This paper presents the results of the tests with the target group. It also compares the results of the paper prototype tests by the expert groups with the results of the digital prototype tests by the target group (see figure 2).

Participants. The digital prototype was tested by 60 persons of the target group. The paper prototype was tested by eleven experts from the field of media didactics and by one expert from the field of OSH. Their expertise enables them to evaluate the comprehensibility of the didactic approach and the game content regarding the relevant subject knowledge.

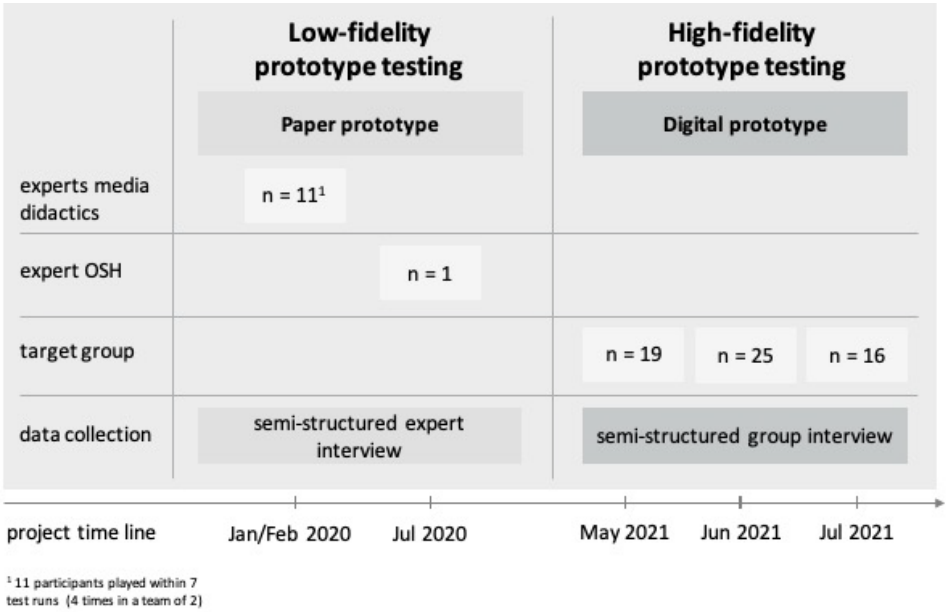


Figure 2: Overview of the test runs

Test procedure. The test runs with the digital prototype were integrated into an online test event in which participants had 45 minutes to individually test the prototype. Afterwards participants were divided into groups and interviewed about their game impressions and perceived knowledge gain using three questions in a semi-structured interview.

The testers of the paper prototype were asked to think aloud (Abidin et al. 2019) throughout playing the game. In the subsequent semi-structured interview feedback on specific evaluation criteria was obtained (Schade and Stagge 2020).

Data collection and analysis. Data was collected through the semi-structured interviews. The testers' answers were recorded and the data was analyzed for content with deductive category formation. The following 15 categories were defined beforehand:

1 First Impression	6 Perceived Increase in Knowledge	11 Fit for Target Group
2 Playing Time	7 Remembered Knowledge Content	12 Negative Aspects
3 Design/Visuals	8 Game Control	13 Positive Aspects
4 Mini-Games	9 Usability/User Guidance	14 Proposals for Further Development
5 Task Complexity	10 Dialogs	15 Transfer of Learning into the Company

The answers to the questions were collected and assigned to the categories. The results of the test runs allow conclusions about how the target group perceived the serious game and their increase in knowledge.

Then these results were compared with those from the experts' test runs with the paper prototype (for the results of the paper prototype tests see Schade and Stagge 2020). Here only nine of the 15 evaluation criteria (1, 2, 4, 5, 7, 10, 12, 13, 15) of the digital prototype could be used for comparison purposes. The reason lies in the differently designed interview questions. In the paper prototype test, a total of ten questions were asked that targeted specific evaluation criteria. In the test with the target group, three more open-ended questions were used due to the group setting. By comparing the data, differences and similarities in the evaluation of the serious game could be identified.

4. Results

The following section presents the results of the test runs with the target group (section 4.1). Subsequently, these results are related to the evaluation of the paper prototype (section 4.2).

4.1 Evaluation of the digital prototype by the target group

1 First impression. It was very mixed: from boring, exhausting, quite okay to entertaining and easy to understand. The jungle setting, eye-catching hazards and puzzles were praised, as was the game's approach in general – even if it caused frustration for some people.

2 Playing time. It was evaluated very differently. Some felt it was brisk. Others felt it was quite long, especially due to the long walking distances. Others – especially older or unexperienced players – felt under time pressure and would have needed more time to fully explore the game probably due to the test setting.

3 Design/Visuals. Some found it very childish, others found it well designed. Especially the color scheme was praised. The visual treatment was very memorable: the very figurative language contributed to an easy understanding.

4 Mini-Games. There was little feedback on mini-games. However, some praised them as a good implementation for entering/exiting the temple. The short knowledge repository displayed at the end of each mini-game, as well as the link to the more detailed knowledge repository, also received positive reviews.

5 Task complexity. Some had problems with the tasks inside the temple (pitfall, extinguishing the fire) and would have liked a short tutorial. A forgotten photo documentation (one of the mission goals) prevented some from easily traversing the temple. Otherwise, most testers found the tasks quite simple and would have liked even greater challenges.

6 Perceived increase in knowledge. Most testers were able to take away some knowledge, even if it was mainly a repetition of pre-existing knowledge. The game acted as an impulse to take a closer look at the topic. Others estimated that the increase in knowledge was not sustainable, especially if the topic of OSH is not a priority in their daily work life. Some users focused more on playing and less on content.

7 Remembered knowledge content. Especially those contents could be remembered where the players had to become active themselves or which were implemented very pictorially, e.g. fire protection, first aiders, or documentation of accidents. Very specific content could also be recalled, for example facts about insurance coverage on the commute to work.

8 Game control. The controls of the game character were predominantly criticized and took time to get used to, which made solving the tasks in the temple more difficult. This was especially hard when playing on a mobile device. Switching between keyboard and mouse was also felt to be annoying.

9 Usability. The main criticism was the lack of orientation within the game environment. The execution of actions in the temple was not intuitively designed. Interaction areas were sometimes not recognizable. On mobile devices, the display of some game content was too small for some participants.

10 Dialogs. The dialogs were often criticized for their large amount of text. They were perceived as funny but also as too childish. Especially the character of the parrot seemed too dominant.

11 Fit for the target group. Some players didn't find the game appropriate, but very childish and not challenging enough. They felt it was more suitable for children/young people and possibly too complex for older people. Others found it very suitable for their own daily work.

12 Negative aspects. The many interruptions and thus the many necessary clicks (e.g. through dialogs) stood out as well as inappropriate sound effects (e.g. exuberant applause). The chosen metaphor on the subject of fatal accidents was felt to be too inappropriate for such a serious topic.

13 Positive aspects. Many liked the idea of a playful implementation to lighten up the theoretical content. It was also praised that the information was conveyed in an understandable and reduced manner. Some sound effects and the possibility to control the game character had a motivating effect. The character of the parrot as a companion and the knowledge repository were also well received.

14 Proposals for further development. Most recommendations for further development related to game play actions and user-friendliness: Testers wanted more action, animation, sounds, and ways to interact with the character (e.g. jumping), as well as more tutorial guidance on completing actions. Additionally, the testers would like to see more references to their everyday working life and more detailed information.

15 Transfer of learning into the company. The knowledge repository was considered very relevant – even more relevant than the game itself. Also the documentary function supported the knowledge transfer. The "very striking" hazards in the game were felt to be easily transferable to the testers' everyday working lives. Some testers felt that the added value was too low and that the game is too unattractive to use it in practice.

4.2 Evaluation of the paper prototype with experts vs. digital prototype with the target group

1 First impression. The game play was perceived as entertaining and fun by most experts. The target group gave mixed feedback – from boring and exhausting to interesting and easy to understand. Both test phases showed that the players needed some time to become familiar with the game.

2 Playing time. During paper prototype testing the playing time was generally perceived as entertaining and optimal. The digital prototype test revealed a very mixed rating: from long to brisk.

4 Mini-games. The mini-games were perceived positively by the experts but the implementation was often criticized, especially their ability to convey knowledge. This feedback prompted a complete revision of the didactic concept of the learning tasks. The target group praised the mini-games as a good implementation.

5 Task complexity. For some testers of the paper prototype, the tasks were easy, others had problems with orientation and the high amount of information. In digital testing it was two-folded: the complexity of learning tasks was perceived as optimal to too easy and game play tasks (e.g. crossing the pitfall) were perceived as difficult to perform.

7 Remembered knowledge content. In the paper-based test little content stuck with most testers – probably due to the initial insufficient effectiveness of the mini-games. The digital tests showed that the players could remember many topics, technical terms and concrete facts.

10 Dialogs. The dialogs were largely perceived positively by the experts, with praise for their looseness and wit. They were also rated as helpful by the OSH expert. Even though the target group perceived the dialogs as funny, they were mainly criticized for their large amount of text and childish character.

12 Negative aspects. Long dialogs and thus the many interruptions were cited as the greatest point of criticism by media didactic experts and the target group. The media didactic experts also rated running back when the documentation was forgotten as demotivating. Some had difficulties with the mini-games as well as with the transfer from game to reality. The OSH expert mainly had content-related criticism (e.g. missing content, more hazard examples). The target group was mainly irritated by some sound effects or metaphors chosen to depict different topics.

13 Positive aspects. The OSH expert and the target group alike especially praised the short knowledge repository as a useful addition. The media didactic experts rated the dialogs, characters and the ambience of the game as positive. The target group praised the animal companion, as well as the idea of the playful implementation of a theoretical topic. They also positively evaluated the possibility to actively move through the game environment.

15 Transfer of learning into the company. All test groups alike rated the documentation as supportive for the transfer into reality. However, the OSH expert criticized that the hazards should have a higher relevance for the target group and a stronger relation to their work routine. A large part of the target group, on the other hand, felt that the "very striking" hazards were easily transferable. Some also praised the knowledge repository. Others felt that the added value of the game was too low for use in practice.

5. Conclusion

The serious game was rated very differently among the target group. While some emphasized the playful approach positively, could handle the mini-games, found the task difficulty easy or even too easy and were able to retrieve knowledge, others were less enthusiastic. They found the game childish and not suitable for the target group, had problems especially with gameplay actions and were not really able to take away knowledge.

In comparison with the paper prototype tests many differences but also some similarities were found with regard to the evaluation criteria. Variations in feedback existed primarily for the evaluation criteria first impression, playing time, remembered knowledge content, dialogs and transfer of learning into the company (criterion 1, 2, 7, 10 and 15).

It is to be examined in more detail below which evaluation criterion can be tested best with which test group. In addition, conclusions can be drawn from the previous paper (Stagge and Schade 2021) about which type of prototype is best suited for this purpose. Table 1 summarizes these conclusions.

Table 1: Conclusions and recommendations for different evaluation criteria based on the serious game E.F.A.

Criterion	Conclusions and recommendations
First Impression	• Feedback from the target group varied from that of the experts • Expert groups can give a first indication of the first impression of a game *Test with the target group at an early stage*
Playing time	• Feedback from the target group varied from that of the experts • Paper prototype only gave an approximate impression of how the playtime was perceived *Test with a high-fidelity prototype together with the target group*
Mini-games	• Experts can sufficiently test the didactical concept and implementation of the relevant content • Valuable feedback for further conception was obtained here – already with a paper prototype and without the target group *Test with experts at an early stage, iteratively improve concept and check with the target group*
Task Complexity	• Experts can already evaluate the general task complexity • For gameplay actions within the game environment, the paper prototype was not suitable *Test with experts at an early stage (for gameplay actions with a higher fidelity prototype), iteratively improve concept and check with the target group*

Remembered Knowledge Content	• Experts have already identified major weaknesses in the transfer of knowledge with the help of the paper prototype *Test with experts at an early stage, iteratively improve concept and check with the target group*
Dialogs	• Feedback from the target group varied from that of the experts *Test with the target group at an early stage*
Negative / Positive Aspects	• Experts already gathered many positive and negative aspects by means of the paper prototype • Feedback from the target group varied in some aspects *Test with the target group at an early stage*
Transfer of Learning into the company	• Experts were able to make an initial assessment, especially the OSH expert • Target group provided a more comprehensive assessment *Test with the target group at an early stage*

It can be concluded that for evaluation criteria 1, 2, 10, 12, 13 and 15, it is recommended to test directly with the target group. In principle, both prototypes are suitable for testing these criteria, except for criteria 2 and 5. Here a high-fidelity prototype is recommended for evaluation. Since simple changes and improvements can only be made to low-fidelity prototypes without great effort, testing with this prototype at an early stage of development should be considered.

6. Discussion and future research

This paper shows that feedback of different user groups of the serious game E.F.A. using different prototypes varies for certain evaluation criteria. Previous research already gave similar indications. For example, Sellen et al. (2009) claimed that prototype formats and tests groups have an effect on the generated feedback. In the literature on human-centered design, a distinction is made between different groups that test as part of the evaluation — for example, experts in a particular field or the target group (Nelles et al. 2018). There, however, the focus is usually exclusively on usability, which was only one evaluation criterion within this study. This work relates to the early testing of serious game concepts and includes a broader range of evaluation criteria. This is in line with the LXD approach which focuses equally on aspects such as usability and interface design as well as on learning experience. In addition, the paper extends the existing research by the aspect of distinguishing between different test groups of a serious game. In Schade and Stagge 2020 and Stagge and Schade 2021 it was already evaluated to which extent different types of prototypes are sufficient for testing serious game concepts. This study now expands previous research by taking a closer look at the test groups while including previous findings on the type of prototypes.

However, the results of the paper stem from a single case study only. Besides, the sample size in the presented assessments was quite small. However, to achieve a comprehensive understanding of the end-users Maheu-Cadotte et al. recommended to test with a small number of the target group, going more in-depth than broad by using qualitative methods such as interviews and focus group discussions. This is suggested already during the early development phase (Maheu-Cadotte et al., 2021). Moreover, the group interview setting used in this study must be viewed critically. Given answers were often adapted to those of previous speakers and possibly answered according to social desirability. Thus, the answers may not be as differentiated as they would have been in individual interviews. Also, during content analysis, when summarizing statements, there is a risk of biased evaluation or over-interpretation of results.

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Developing an Evaluation Framework for Analysing Educational Simulation Games

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Abstract: Despite the emergence of new methodologies for analysing and evaluating games using usability testing and heuristics evaluation frameworks, there is still lack of inclusive game heuristics for analysing educational simulation games. To address this, we conduct two case studies: professional critic game reviews and focus group interviews. We have looked at the effects of games on players' gaming experiences in different gaming context (i.e. playing educational versus (vs.) entertaining simulation games). Findings show various game design similarities & differences between playing these simulation games. It also highlights game design issues. In this paper, we propose a new game evaluation heuristics model (GADDIE) that consists of Game Analysis (GA), Design (D), Development (D), Implementation (I) and Evaluation (E). These heuristics were compiled as a result of game design issues identified from the professional critic game reviews and the focus group interviews. On the basis of the data obtained it is argued that the GADDIE model could provide further guidance that leads on from previous research, since it encapsulates research findings, game design principles, human computer interaction, usability testing guidelines, educational perspectives and overall our experiences as educators and game researchers. Consequently, the proposed framework would support our ongoing research project in game evaluation process (educational vs. entertaining), and other researchers, more effectively.

Keywords: game evaluation heuristics, usability testing, game design, human computer interaction, simulation games

1. Introduction

In recent years, the role of game design has become increasingly significant, especially in the field of user-centred design, as more professionals are developing new methodologies for analysing and evaluating games using usability testing and heuristics evaluation frameworks. Usability testing is a field originated from Human Computer Interaction (HCI), aimed at designing easy-to-use interfaces and activities (Nielsen, 1995, 2000; Desurive, et al., 2004). Whilst usability testing is a key process in designing innovative technologies in industry and particularly in game design, analysing and evaluating games necessitate evaluation heuristics and guidelines. This can be demanding since a comprehensive framework for evaluating educational and entertaining simulation games, from various perspectives such as game design principles (Schell, 2015, 2020), HCI, usability testing guidelines (Falstein and Barwood, 2001; Desurive et al., 2004) and educational purposes, is complex and challenging. To address this, we present a new set of game evaluation heuristics from multifaceted perspectives for educational simulation games, such as game design principles, HCI, usability testing guidelines and educational/theoretical perspectives. For this purpose, educational simulation games are considered in regard to their intended learning purposes as well as their engaging properties as games. They must have clear learning objectives to succeed educationally, if they are not engaging or enjoyable as games they will fail. Whilst entertaining games like Massive Multiple Online Role-Play Games (MMORPG) are intended to concentrate on entertainment rather than learning. MMORPGs are a type of entertainment games, a subgenre of action games, which involve strategy, fantasy, adventure, and simulation. Simulation games (SGs) are games set in an interactive environment where players apply knowledge/skills to solve complex problems.

In this paper, a brief overview of the development of game heuristics is given, highlighting usability evaluation guidelines and game design principles.

2. Game Design and Development: Objectives & Methodology

2.1 Evaluations Heuristics, Game design and HCI principles

Game evaluation heuristics are regarded as a set of design guidelines and they are closely linked with more general design principles relating to the usability of interfaces (Malone, 1980). They are important because they play a major role in the software development life cycle where the aim is to develop new software design after

several iterative stages of implementation. There are several heuristics available like HEP (Desurive et al., 2004), MDA (Hunicke et al., 2004), PLAY (Desurvire and Wiberg, 2009), GAP (Desurvire and Wiberg, 2010), Heuristics for Social games (Paavilainen, 2010), GameFlow (Garris et al., 2002; Sweetser and Wyeth, 2005), Gamification Heuristics (Tondello et al., 2016), the taxonomy of leaning elements of digital games-based learning experiences (Whitton, 2011) and Gee's (2003, 2007, 2011) 13 learning principles. These heuristics can be visualised as follows:
HEP -> MDA -> PLAY -> GAP -> Heuristics for Social Games -> GameFlow -> Game Heuristics -> Taxonomy of Learning of Digital Games -> 13 Learning principles

Even though these heuristics are valid and useful, they appear, however, isolated, repetitive and some do not adhere to HCI principles, usability testing guidelines and educational perspectives simultaneously. For example, Heuristics for Playability is a list of heuristics based on the literature and usability testing for evaluating the usefulness of computer, video and board games, developed by Desurive et al (2004). However, this method is broad and unsuited for evaluating specific issues in the software development and HCI game usability and playability (Desurvire and Wiberg, 2009). Moreno-Ger et al. (2008, 2012) on the other hand, developed a step-by-step methodology for educational games intended for training purposes whilst Whitton (2011) developed a taxonomy of learning elements of digital games.

In this paper, we feel that there is therefore a necessity to develop new game evaluation heuristics based on both computing and educational perspectives, as aforementioned, i.e. HCI principles, usability testing guidelines, educational perspectives and our experiences as educators and game researchers. Furthermore, these heuristics are grounded from the empirical data outcomes and thus offers insights into a new way of employing these heuristics to investigate the effects of games on players' gaming experiences (a transformation/ a journey: for the better/ worse) (Schell, 2015, 2020), by examining closely how players employ language to express their game experience. This is because for educational games additional features have to be accounted for such as game story, mechanics, engagement, feedback, challenge, entertainment and assessment (Nielsen, 1995; Gee, 2011; Whitton, 2011; Schell, 2015, 2020; Arnab, 2017). It has been argued that these elements should be balanced in order to create a game worth playing (Desurvire and Wiberg, 2010; Schell, 2015, 2020). Due to differences in the above approaches, a new set of design principles is necessary.

2.2 Research Objectives

The *research objectives* of this study were:

- What is the relationship between SRPGs (simulation roleplay games) and game players?
- What are game players' feelings/ experiences towards SRPGs, game design, gameplay and development?

2.3 Sample

Study 1 consisted of 40 professional critic reviews of simulation games from the Massive Multiple Online Role-Play Game (MMORPG) website (http://www.mmorpg.com/gamelist.cfm). These were chosen since we are interested in exploring game design, gameplay and development.

Study 2 consisted of three focus group interviews (FGIs), 24 participants (males and females). These volunteers were recruited from our university. They are studying Computing & Business Computing Degrees, our area of interests. We chose these participants because we are interested in exploring their experiences with educational games.

In this paper, we will use the emerging data from the professional critic game reviews and FGIs as a grounding tool to elicit meaning, and players' interaction with the game as a system, and derive the effects of games on players' gaming experiences, and whether it was a transformation for the better or the worse.

2.4 Methods of data collection

The empirical studies were conducted in a series of professional critic game reviews (study 1) and three FGIs (study 2) in the autumn semester for six months. Study 1 consisted of professional game critic reviews of simulation games from the Massive Multiple Online Role-Play Game (MMORPG) website (http://www.mmorpg.com/gamelist.cfm). Reviews of a range of 6 games were collated for analysis from the MMORPG website: Destiny, 4Story, 9Dragons, Black Desert Online, Blade and Soul, and Defiance. I will be referring to these games as simulation games or a game to avoid repetition and since we are interested in game

design and development rather than any specific game. These simulation games were selected due to their popularity, user rating and highest scores on the MMORPG website from 7.1 score to 8.57. Both positive and negative reviews were selected. Reviews with a few words were discarded using this process at least 8 reviews for each game were analysed comprehensively bringing this to a total of 40 professional critic reviews. Whilst study 2 consisted of 24 undergraduates (males & females) who were interviewed, in a series of three FGIs, about their feelings, interactions and experiences with games, and what effects games have on their gaming experiences, in particular educational games. The professional critic game reviews and FGIs were recorded, transcribed and analysed using adaptive method.

2.5 Process of data analysis

We used an adaptive method to analyse qualitative data. 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 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 the theoretical model. At this stage, all the coded data were linked back to the literature. The forty professional critic games reviews (study 1) are referred to as P1, P2 & P3 (players)…etc. The responses from the professional critic games reviews were grouped into the following categories of game analysis: Gameplay, game story and story lines; game design and development; game implementation and evaluation. The choice of these categories was made so that data analysis could be undertaken systematically. Recordings of these professional critic games reviews were examined in detail so that we could make note of themes, as afore-highlighted. These professional critic games reviews were then linked back to the literature review. Similarly, the 24 participants (FGIs: study 2) are referred to as M1, M2 & M3…etc (males) and F1, F2 and F3…etc (females), where applicable. The responses from the FGIs in particular game design & development elements/ issues were collated to build the GADDIE from educational perspectives. Recordings of these FGIs and the transcriptions were examined in detail so that we could make note of themes. The FGI responses were then linked back to the literature review. The emerging themes, patterns and categories were highlighted and consistent with the literature review, game design and usability guidelines.

3. Results

Both findings indicate sophisticated game design issues that affect immensely players' experiences - in both case studies- since not all players had an enjoyable experience as research data revealed and this is due to lack of game usability heuristics, HCI principles and many game design issues (Figure 1).

The professional critic game reviews looked at the effects of games on players' gaming experiences and feelings. Similarly, the FGIs (as aforementioned) looked at players' gaming experiences, feeling and the way they construct their realities. Then comparison was made into whether there are any similarities or differences between games, game design, gameplay and development. Interestingly and even though entertaining games are highly developed with multi genres, some players still reported a negative experience. Hence both studies (& despite exploiting two diverse types of games: Entertaining & educational games) suggest that gameplay besides levels, game contents, rewards and feedback, as a key tool to play, are significant mechanisms in determining whether players have an enjoyable experience and whether they continue with their gameplay or stop. Our findings thus suggest that game story is the main driving force behind keeping players engaged and entertained whilst interacting with games, whether it is educational or entertaining games and this provides the basis of the format of the heuristics shown in Figure 1. We identified entertaining games (as mentioned earlier) like the MMORPG. MMORPGs are of type entertaining games, a subgenre of action games, which constitute of strategy, fantasy, role-play and adventure. Whilst educational games (as defined previously) are regarded as games that are intended for innovative learning purposes in mind other than just entertainment i.e. educational. These games have a combination of fun, play and learning (Falstein and Barwood, 2001; Garris et al., 2002; Mullins, 2013). Interestingly, results from both studies suggest many rising themes emerging emphasizing the role of game design principles, usability heuristics with all its game mechanism such as story & storylines, motivation, graphics, design, sound, aesthetic, mechanic and usability testing issues. We will argue that findings suggest that heuristics principles and game design affect players' gaming experiences and how they perceive the game afterwards.

4. Game Analysis

4.1 Gameplay

There is a great deal of emphasis on gameplay, "doing things that are fun and you don't think about it...you just concentrate more and you have great fun" [F1, study 2]. Gameplay requires clear objectives, concentration (Garris et al., 2002; Koster, 2005, Figure 1), "[a]vision", "showdown system… tutorial" and "game contents" besides levels "they're only level 100-105" [P1, study 1]. This highlights the fact that comprehensible outcomes (behaviour outcomes: cognitive, affective (attitudes) and psychomotor (skills)) or objectives of the game are essential (Mayer, 2014) besides constant feedback and progress display: scores and levels (Schell, 2015, 2020). Nevertheless, some players characterize gameplay as "[d]isappointing" with "no real risk and reward incentive… to continue", adding "long term playability severely lacking" [P1, P2, P4, P5, study 1]. Whilst P3 stated that "despite a tutorial" he "dislike[d] it a lot" [study 1]. This is implicitly due to ambiguous outcomes that caused disappointment and disengagement. This disengagement is what our FGI participants referred to as when [the game] "does not go anywhere completely repeating same things over and over again. No amazements or competition, no self-satisfaction, no mission, no variety, no direction [and] no hints" [M1, M2, M3, M4, F1, F2, study 2]. On the whole, this will cause "dislik[ing]" of the gaming experience instead of enjoying the gameplay experience. The game was therefore not self-intuitive as indicated by Nielson (1995, 2000) and rather complex leading players not to understand the game and thus hating the game. Based on Mullins' (2013, 2019) basic motivational model, when needs/ expectations are unmet this results in driving force or a change in behaviour (e.g. dislike of the game experience) because lack of desirable goals/outcomes that led to a gap or no fulfilment. This is because if players could not understand the rules of the game- in order for engagement to take place i.e. lack of understanding the rules of the games' "tutorial" with no reward or risk incentives (Garris et al., 2002; Salisbury & Cole, 2016)- this will lead to unmet expectations or needs that subsequently act as a driving force/ change in the attitudes resulting in disfavour of the whole gaming experience (Federoff, 2002; Slyman, 2014; Mullins, 2013, 2019).

4.2 Game Story and Storylines

Furthermore, game story and storylines emerge as a fundamental tool for engagement (Garris et al., 2002; Figure 1), since "gameplay, and overall design of the game" were found to be "amazing" because this leads to a "pretty awesome" experience [P1, P4, P26, P31, study 1]. This is because "[g]reat storyline…is based on unique skills and character development" [P5, study 1]. In addition, the driving instincts of the game & how the story is built are incredibly essential. As the suspense; the events; the conflicts; the story with its characters and graphics; the novelty and dramatic changes are significantly challenging and inspiring so that players are kept engaged and coming (Malone, 1980; Schell, 2015, 2020). However, some players delineate the game as "[n]ot a good game", a "clone", "not original" and "a pretender" as, [P7, P12, P14, P18, P21, P22, P23, P37, P38, P40, study 1] stated, "it lacks a lot of actual content and feels repetitive after a couple weeks of grinding". This is because if the game's storyline is not appealing i.e. "[n]ot good" or a "clone", this will lead to disengagement. As some players stated, "I couldn't really get into this game it wasn't for me, [I] was bored" [P10, study 1], it is in fact less appealing and "boring" [F1, M1, study 2], since there is "no mission, no variety, no direction [and] no hints" [M1, F1, study 2]. This suggests that the driving instincts of the game & how the story is built were not exciting/ appealing (Moreno-Ger et al., 2012; Schell, 2015, 2020) in fact it was unexciting gaming experience for some, since players could not "get into this game" and so understand the game in a cyclic iterative way. This presumably signifies the significance of the game story to be a generating machine story that captivates players leading them to return to the game each time as stated by Schell (2015, 2020).

In addition, others "[dis]like graphics" and "quests" because they find the game "not that fancy" [P5, study 1] exciting or appealing (Moreno-Ger et al., 2012; Schell, 2015, 2020; Figure 1). It is in fact "simple just not fun", suggesting that players felt disengaged and not immersed in the gaming experience though "it left a bad impression" [P8, study 1; M3, study 2]. On the contrary, other players cherish the gaming experience and the effects of the game on their emotions stating clearly, "[i]t is [the] ultimate fun" and they "love this title" [P10, study 1], signifying that the game is fun and enjoyable due to the fact that the element of play is present, engaging and it is the "ultimate fun" [P9, study 1] and [it is about] "doing things that are fun" [F1, study 2] (Figure 1). This is because games in game design are expected to challenge, engage and stimulate the mind of its users in a fun and appealing manners (Moreno-Ger et al., 2012; Schell, 2015, 2020)

4.3 Game Design & Development

Furthermore, game "mechanics," "animations," "graphics" and "sounds" are characterized as "fantastic" by some suggesting that game mechanics, aesthetic and technology are working in harmony [P1, P3, P5, P25, P26, study 1]. This also highlights the fact that animations, sound effects and graphics increase players' enjoyment and curiosity (Schell, 2015, 2020). These are fundamental characteristics in game design and development (Schell, 2015, 2020). In addition, the aesthetic components of the games should be engaging and entertaining, since players can become disengaged with the games, as the game can "get boring real fast". On the other hand, others put emphasis on technology and how it is crucial in game design, as "lack of meaningful content" and "disappointment" can lead to "shallow and repetitive" gaming experience. This also signifies how game story, content, aesthetics and usability principles "responsive movement and controllers" should be adhere to in game design (Falstein and Barwood, 2001; Schell, 2015, 2020) else this will result in a repetitive experience and generally players "do not want clones of other games" [P7, P14, P15, study 1]. Game players require games that are challenging with hidden problems/conflicts as a part of gameplay: A story machine generator, where the game generates more problems and keep players engaged and coming (Sweetser et al., 2012; Schell, 2015, 2020; Figure 1). This seemingly implies the significance of game novelty from story, design to mechanics and usability principles and this is very much related to game heuristics framework (Figure 1).

5. Game Implementation & Evaluation

5.1 Usability Principles

Other interesting emerging themes are usability principles where user interface and mechanics were not accurately functional. As "controls" and "immersion hit to a low standard", declared [P7, study 1], while usability issues, lack of useful feedback: "not user-friendly", "stale" interface and error handling message "a few bugs" (Nielson, 2000), promoting users to undo their action (Nielson, 1995; 2000), were critical issues that caused fatal technical errors causing the game to "stop… loading" [P8, P33, P34, P38, study 1](Silverman et al., 2003). This implicitly suggests that Nielson's (1995, 2000) heuristics like error handling and feedback message are missing or not adhere to in game design.

5.2 Socialising and Online Payment Upgrading Systems

On the other hand, it is worth noting that socialising and online payments upgrading level system heuristics were frequently mentioned this is because, we believe, that in today's fast-paced digital technology arena, these 'generation' of players (Horn et al., 2016) exploit the internet as a means of social interaction and networking. This also emphasizes that these generations like to socialise more and pay for online goods, and this plays a significant role in the gaming experience whilst others thought that "not many people like to group" [P18, study 1], indicating that some people did not like socialising. This also implies that a number of game players prefer socialising [M2, F2, study 2], while others do not like to interact/ chat online. In contrast, one player [P7, study 1] suggests that games should involve "other members as well like in real-life because in real-life you work with other people", emphasising that teamwork and collaboration are crucial skills in life.

6. Discussion

6.1 THE GAME HEURISTICS MODEL: GADDIE

The proposed game evaluation heuristics model shown in Figure 1 is designed to fulfil a gap in the existing literature as previous game heuristics models were either based on entertaining or educational games perspectives but there is not a balance. The research focus thus is to design a game heuristics model that is grounded from the data, combined with HCI principles and usability testing guidelines, and the researchers' experiences as computing educators and game researchers. Consequently, this result in the GADDIE model consisting of five phases: Game Analysis, Design, Development, Implementation and Evaluation (GADDIE), since we trust that these mechanisms are major ingredients in game design be it for entertaining or educational games. The GADDIE model phases are: Game Analysis (This includes analysing players' gaming characteristic, their current levels and styles; the outcomes and any existing constraints they might encounter); Design (houses for instance designing user's experience taking into consideration the cognitive and affective factors and how the game is displayed with its visual, technical and graphical design, which will influence the outcomes); Development (This may include integrating technologies, testing, debugging and reviewing it before final release); Implementation (This involves training facilitators/game players according to the outcomes or curriculum design we would like to implement specifying its method of delivery and testing procedures) and Evaluation (i.e. Formative & summative assessments/ evaluation of the whole design. This includes testing

design and providing opportunities for feedbacks). Consequently, the game heuristic model symbolises a better game evaluation framework categorised according to these phases that were embodied in the framework as game analysis, game design & development, and game implementation & evaluation. Having analysed both findings, as aforementioned, it is worth noting that some heuristics were supported immeasurably while others were not. The theory behind implementing such a model was to profoundly build a constructive framework that will formulate the backbone/ basis of game evaluation heuristics, for analysing our future games (entertaining vs. educational).

The game analysis phase (I) consists of Gameplay. Gameplay has twenty heuristics, from (1.(I) to 20.(I)). It deals with how the player interacts with the game starting with the **game objectives**, players' **preliminary skills** to commence the **game, levels, styles and genres of the game, engagement, surprises** and curiosity to **game story** and how the scene is built up, and whether the **game** is **fun** and **transforms** its players for the **better** or **worse**. **The game story** was remarkably and immensely repeated copiously in both the focus group interviews and the 40 professional critic reviews, and we trust this is the **main drive that motivate players' to continue with the story** or ended it, as the analyses findings revealed. Gameplay also analyses whether the game has **risks**, clear **tutorial & documentation**, constant **feedback**, simple or complex play/ interaction, and if it has an **online upgrading** system; **pay-in** system and clear outcomes of the game.

The game design and development phases (II) have nine heuristics from 1.(II) to 9.(II). It consists of **game mechanics, aesthetics and technology**. This may involve **animation, sound effects, game educational, visual and technical design like menu, attributes to objects, and inputs and outputs resources; Game storylines** and how its design are developed and whether its parts are **integrated harmoniously**, interactive (with the interface and controllers) and **easy-to-use**. As well as online payments system-Upgrading game levels

The game implementation and evaluation phases (III) have from 1.(III) to 13.(III) heuristics. It deals with game usability and how **accessible** and **usable** it is for players to interact with the game. It investigates whether **training** facilities, **outcomes**, **curriculum** and methods of delivery are clear, adding to this **progress, feedback, scores & levels, and checking that they are explicable, challenging & balanced** according to levels. In addition, it examines if game **storyline is stimulating, novel, logical and well designed with engaging** outcomes. It also assesses whether the game has **accessible user-friendly interface** that is consistent throughout the game interface with its **menus design, controllers, sounds and animation** that do not confuse players, and can **handle error message** easily, with **accessible tutorial** and **documentation, and friendly online customer support service.**

The rationale behind this research, as stated, was to generate a comprehensive model for analysing entertaining and educational games and thus create a better game design that caters for players' needs and expectations, leading users to **progress** during gameplay and achieve **fulfilment**.

Key
I.II, III: GADDIE Phases
1., 2., 3,: Sub-categories

Phases & Categories	Heuristics & its description
I. Game Analysis (Gameplay and Game Story)	1. (I) **Clear objectives or outcomes** of the game. 2. (I) **Players do not require any preliminary skills to commence.** Novice/ experts can understand the rules. 3. (I) **Game styles/genres** are distinctive: strategy/ adventure…etc. 4. (I) **Expectations and needs** (behavioural outcomes: cognitive, affective (attitudes) and psychomotor (skills)) are achieved leading to **progress** and **fulfilment** (i.e. positive experience). 5. (I) **Levels** are obtainable/ easy/ hard. 6. (I) The element of **curiosity and manipulation** are **integrated** in the game. 7. (I) Players are **engaged** in the game. The **game** is **valuable** and **players care** about it. 8. (I) Game players are asked to **solve challenging hidden problems/conflicts as a part of the gameplay**. The game generates more problems to keep players engaged and coming. 9. (I) The **driving instincts of the game & how the story** is built are exciting/ positive/ boring. The suspense; event; story; characters; details; and dramatic changes are balanced/ appealing. 10. (I) The **game is fun & enjoyable**. Some parts are/need to be fun. The element of play is

Phases & Categories	Heuristics & its description
	presented in the game and it is engaging and immersive. 11. (I) The **game surprises** the players when they play. The **game story** has surprises. The rules of the game give players ways to surprise each other and themselves. 12. (I) Games can **transform players for better/ worse.** The game is **worth playing/** the time. 13. (I) **Risks; choice and chance; punishment; competition**; reward is built up. A way to turn loosing state to a winning state. 14. (I) **Constant feedback, clear progress** display (scores and levels) and response time. 15. (I) **Players** are able to **socialise/ express themselves.** Some/ all are playing with friends. 16. (I) **Simplicity/ complexity** is/ should be balanced. 17. (I) They are **puzzles/quizzes** in the game. 18. (I) **Tutorial** & **documentation** is clear and comprehensible. **19. (I) Online Equipment Payments- Upgrading system.** **20. (I) Clear outcomes of the game.**
II. Game Design & Development (Game Mechanics, Aesthetic & Technology)	1. (II) **Animation and sound effects work in harmony.** 2. (II) **Reward and feedback** increase **players' curiosity and engagement.** 3. (II) **Game instructional, visual and technical** design: venue, objects, attributes, dimensions 2D), novelty, uniqueness; imagination, strategy, constraints/ limitation, effects are distinctive. 4. (II) **Storyline** is easy to understand, clear with **engaging** outcomes/vision. 5. (II) **Game designs with its different elements** are in **harmony**. The game time is short/slow/fast. 6. (II) **Physical input & output resources are appealing** from aesthetics, mode of change, size, font and colours. 7. (II) **User interface**, controllers; **feedback/** reward and spending money, currency/ points all information are obvious and communicated to the user without interfering with the interface. 8. (II) **Technology and programmes** are **harmoniously integrated.** 9. (II) **Online payments- Upgrading game levels.**
III. Game Implementation & Evaluation (Game Usability)	1.(III) **Training facilities and outcomes** are distinctive. 2.(III) **Curriculum and methods** of delivery are clear. 3.(III) **Progress, feedback, scores & levels are explicable, challenging & balanced** according to levels. 4.(III) **Points/ reward** is built up. 5.(III) **Storyline** is suitable for the **level of complexity.** 6.(III) **Storyline** is **logical with engaging outcomes/ vision.** 7.(III) **Storyline** is **novel.** 8.(III) **Storyline** is **well-designed.** 9.(III) **Intuitive accessible user-friendly interface**; consistency **throughout the game interface**, menus, design, sounds and animation. 10.(III) **Controllers** do not confuse the players. 11.(III) **Useful error handling message**, promoting users to **undo their action**. 12.(III) **Tutorial** & **documentation** is **easy** to read and understand. 13.(III) **Friendly Online Customer Support**.

Figure 1: GADDIE: The Game Evaluation Heuristics

7. Conclusions

This research paper has highlighted the effects of games on players' gaming experience for educational simulation games using the heuristics framework, the GADDIE model. This encapsulates game design principles, HCI usability guidelines and educational perspectives. These heuristics were designed based on the research findings and game research literature. These heuristics are intended to **aid our ongoing research project** for **game analysis and evaluation** since research findings reveal that game design heuristics **affect** players' **gaming experience** whether it is for entertaining or educational games. Results found that evaluating games for usability present unique challenges and require heuristics that aim to reflect how users should interact with **games in a cyclic iterative way because if users' needs or expectations are unmet, this will lead to frustration/ undesirable behavioural outcomes when assessed.** This subsequently will cause displeasing gaming experience that should have been motivating & enjoyable. **Usability issues** should **encapsulate gameplay** (goals and challenges of the game), **game interface** (visual & physical aspects like screen) and **game mechanics** (internal aspects of the game: animation, coding…etc). **Game usability heuristics** are usability principles, a quick and inexpensive method of

evaluating the usability of the software for two to three hours aimed at enhancing and improving game design and development.
In this empirical study, the contributed heuristics from the professional critic reviews & FGIs (as aforementioned) were collated and compiled to make our **GADDIE model**. These heuristics are regarded as incredibly significant as the findings reveal (Figure 1). We recognize the values of other heuristics such as Game Physics and Artificial Intelligence that were not supported by our case studies but the ones we discovered are originated from our empirical case studies, and what educational simulation game researchers should emphasis more.

For future research, this empirical work could be developed further using, for instance, observation methods such as eye tracking systems or brain scanners (functional magnetic resonance imaging) to monitor brain activity that is responsible for behaviour, attitudes and feelings, excitement or disengagement during gameplay. It can therefore pinpoint reasons that trigger unpleasant gaming experiences (a transformation for the worse) and enable the advancement of effective strategies for dealing with game design issues in order to improve **game quality design that meet users' expectations**. This study offers a new way of designing game evaluation heuristics for better game designs from HCI design, usability and educational perspectives, and this is the **true value of our contributions** because **this paper is part of ongoing research project for analysing and evaluating educational simulation games**. This research paper indicates several game design issues that affect players' gaming experiences and necessitate the design of a new set of heuristics (a check list) for a better game analysis and evaluation for educational simulation games, which was the aim of this research paper.

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Missions with Monty: A Game-Based Learning Environment to Promote Comprehension Monitoring and Science Achievement

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Abstract: While game-based learning environments (GBLE) are an increasingly popular means to engage learners, there remains limited research on the benefits of GBLEs for students' learning and metacognitive skills in classroom contexts. Missions with Monty is a GBLE developed to engage students as they learn comprehension strategies to support their scientific literacy with targeted Next Generation Science Standards content. The current missions focus on ecosystems, earth and human activity, molecules, and organisms. Students navigate through the game to solve challenges that require the application and transfer of science knowledge. One primary and unique focus of Missions with Monty is to benefit students' metacognition through comprehension monitoring. Comprehension monitoring is an essential strategy to support literacy and is measured through students' accuracy in rating their performance on comprehension items. In the game, students are explicitly taught and subsequently practice essential comprehension monitoring strategies. Additional key educational outcomes for students playing Missions with Monty include reading achievement, science knowledge, and transfer of science learning. In this study we examined 10 and 11 year old students' outcomes as they either played the game (n = 144) or learned the content via a computer-based learning environment (CBLE) without game elements in a comparison condition (n = 80) within classrooms of diverse learners in the United States. Significant gains for science learning were found across conditions, ($t(223) = 13.67$, $p < .001$). The primary research question of interest focused on whether students who played Missions with Monty were better able to monitor their understanding of science text after playing the game and therefore we compared monitoring, as measured by bias and accuracy, before and after the game play. Effective metacognition is demonstrated by low bias and high accuracy. Findings revealed that both conditions demonstrated improved bias ($t(223) = 4.44$, $p < .001$) and accuracy ($t(223) = 11.81$, $p < .001$). Thus, students were better able to monitor their science learning through the game, an essential skill for scientific literacy. Future research should continue to examine the benefits of GBLEs versus CBLEs in terms of benefits for motivation and learning.

Keywords: GBLE; STEM learning; Scientific Literacy; Metacognition; Reading Comprehension

1. Introduction

Well-designed GBLEs can benefit students' learning outcomes as well as their self-regulated learning (SRL) (Nietfeld, 2018). SRL encompasses cognitive, affective, and motivational elements (Clark et al., 2016; Connolly et al., 2012; Sailer & Homner, 2020). Characteristics such as goal-directed play and the ability to examine navigation paths and engaged strategy use suggest that GBLEs may be particularly well-suited for examining SRL elements. GBLEs provide a rich context to study and support students' SRL while augmenting typical traditional classroom environments. The goal of *Missions with Monty* is to support students' science literacy and comprehension monitoring, a key component of SRL. Students' display effective metacognition through comprehension monitoring, where students reflect about how well they understand the content that they are reading. Comprehension monitoring includes both evaluation and regulation activities when learning from text (Hacker, 1998). This includes a reader evaluating the extent to which they comprehend a text and subsequent attempts to regulate fix up strategies to improve any inadequacies with comprehension. Accurate comprehension monitoring is critical in order to judge what information needs to be reread or restudied and it is therefore important to train students to make accurate monitoring judgments (Huff & Nietfeld, 2009). *Missions with Monty* provides support for essential science content learning by equipping students with science literacy skills through comprehension monitoring strategy training. Educational games that emphasize science learning are prevalent; however, most do not attend to the importance of reading comprehension and comprehension monitoring.

Previous GBLEs have likely avoided supporting reading comprehension and monitoring given the many challenges that arise when teaching effective SRL strategies. Designing a game environment that can effectively scaffold the complex processes and strategies for SRL reading is exceptionally challenging as breakdowns in comprehension can occur for various reasons related to self-regulation, including deficits in prior knowledge

(McCarthy & McNamara, 2021), metacognitive monitoring (Follmer & Sperling, 2018), and motivational factors, such as low self-efficacy (Schraw et al., 2006), interest (Renninger & Hidi, 2015; Springer et al., 2017), or lack of a mastery-based approach (Seaton et al., 2014). SRL abilities develop in late elementary school and this provides a critical opportunity to intervene and support SRL with comprehension monitoring scaffolds (Tonks & Taboada, 2011). Regardless of the fact that little time is spent teaching effective comprehension monitoring strategies, students need to engage in successful reading and reading of science text (Blachowicz & Ogle, 2017). GLBEs are well-positioned to address this challenge; they offer a unique space to scaffold learning through explicit training, practice, and timely and customized feedback, all while providing the engaging elements that games offer.

Even though there is a deep and growing literature of metacognitive interventions and programs for upper elementary students in traditional classroom settings, there is surprisingly scant research focusing on metacognition in GBLEs (Braad, et al., 2020). Exceptions have included work in the *Crystal Island - Outbreak* GBLE where metacognitive response bias predicted game performance even after accounting for prior knowledge and motivational variables such as self-efficacy, interest, and goal orientation (Nietfeld, et al., 2014). Also in *Crystal Island*, Taub et al. (2018) used sequential pattern mining to distinguish between more and less efficient learners by revealing that more efficient learners tested fewer partially-relevant food items. Alternatively, Riemer and Schrader (2020) found that self-monitoring was related to learning outcomes only for students with a low or moderate competition preference when playing an entrepreneurship game. While these studies provide a useful start in the examination of metacognition in GBLEs, the field is open to the exploration of numerous topics, such as the role of metacognitive judgments in academic learning, that dominate much of the literature in traditional classroom environments.

2. Game Design

Missions with Monty (see Figure 1) was developed with a multidisciplinary team of educational psychologists, educational technology specialists, developers, curriculum specialists, and designers. The game was created to align with how teachers and students commonly use educational games: on laptops and tablets. Importantly, *Missions with Monty* was developed to support learners' science literacy skills and comprehension monitoring strategies within the context of learning from informational science texts. All science content in the game was developed to align with standards not only at the classroom and state level, but also nationally (e.g., Next Generation Science Standards). For example, informational texts cover content about ecosystems, energy, and Earth and human activity. The program's organization prioritizes science content presentation through texts embedded within 'missions' or units; across missions, a consistent narrative is present and endorsed by other game characters who are experts in their respective mission's content.



Figure 1: Reading text presented by animal researchers in *Missions with Monty*

Students start *Missions with Monty* by accessing an animated video that provides the game's narrative background. Students learn that they have been invited to work with Monty, a monitor lizard and famous scientist. Monty is also the founder of Wildlife University (WU), which is situated in a rainforest. WU was established not only as a base for Monty's research work, but also to support students' and professors' development of science literacy. The students and professors at WU are working hard to learn about ways to save their natural habitats. Once players arrive at WU, however, they quickly learn about two major problems: the students and professors at WU have become ill, and Monty is missing. Learners are tasked with two major gameplay goals: *1) learn as much as possible to figure out why the animals at WU are sick, and 2) identify who kidnapped Monty*. To accomplish these goals, players are informed that they will be supported by Monty's colleagues, who are experts in the science content students will learn.

Given the focus on SRL to support their learning and navigation, before the first mission, players complete a 'training camp' (see Figure 2) led by support-team 'professors' specializing in highlighting, summarization, and monitoring. Students were trained to selectively highlight main ideas to encourage a focus on quality, self-regulated highlighting, self-assessment, and revision (Leopold & Leutner, 2015). Summarization was also chosen to focus the player on succinctly recognizing and conveying the main idea of a text. Summarization has been shown to lead to improved comprehension monitoring accuracy (Thiede & Anderson, 2003). Of specific focus for the current study, monitoring accuracy assessed students' ability to calibrate their judgments of confidence with their actual performance on science items presented by game characters. Calibration as an index of metacognitive monitoring has been shown to relate strongly with academic performance and even predict efficiency in game-based learning contexts (Nietfeld, et al., 2006; Nietfeld, et al., 2014).

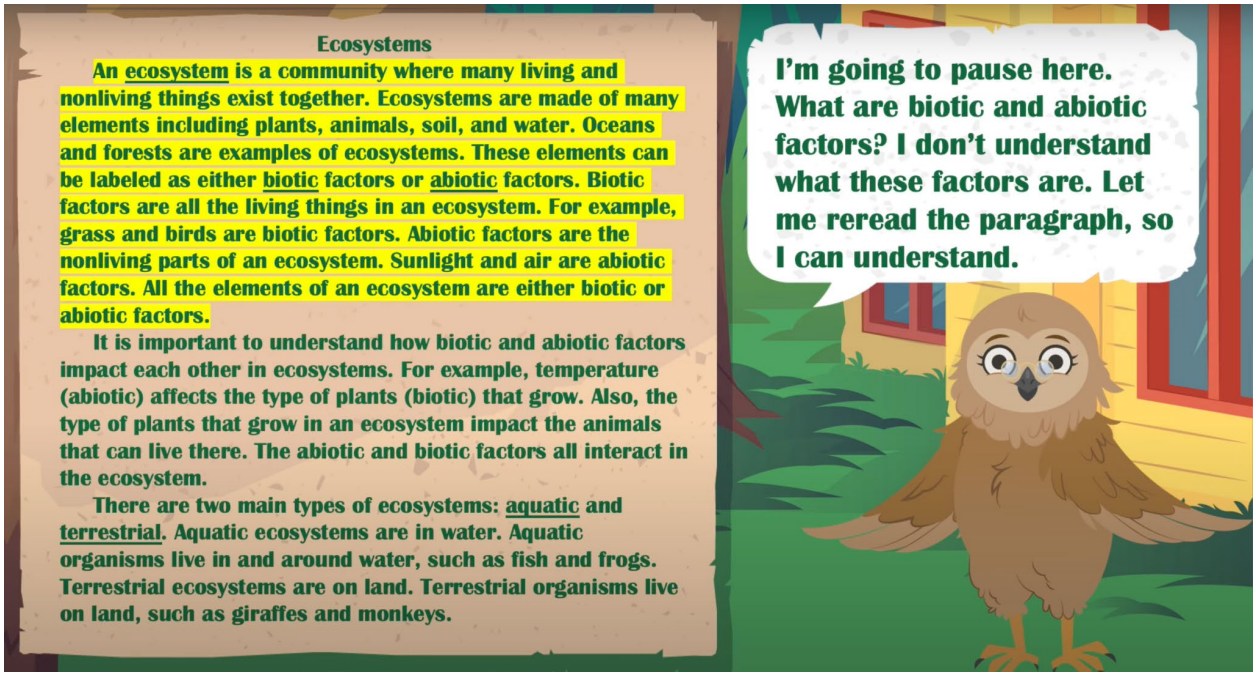


Figure 2: Monitoring training

After completing training camp, students embark on a total of three missions, which are framed as research camps in the rainforest, ocean, and savanna. Within each mission, students access various research sites that are further organized by content. At each research site, the assigned game character introduces learners to informational science texts and other gamified features in the respective environment. The texts and assessments employed in the gamified challenges were previously vetted in a validation study conducted within the grant project. In addition, the texts include additional sources of information, such as pictures, data charts, and representations. Students engage with the texts in a standard format at each research camp:

1. Read a text presented by a character and highlight the most important ideas.
2. Engage in a Highlighting Challenge where the player selectively highlights the most important sentences.
3. Engage in a Summary Challenge to identify the best summary from an expert-generated list.
4. Engage in a Knowledge Challenge to answer content items.
5. Engage in a Monitoring Challenge to provide confidence judgments.

6. Examine feedback on Knowledge Challenge answers and color-coded, customized feedback regarding their Monitoring Challenge judgments.
7. Complete the aforementioned steps for each passage in the research site.

In *Missions with Monty*, multiple-source understanding is essential to solve the overall problem of the game. Therefore, students engage in research site level and mission level multiple-source integration challenges called the Moment of Truth presented by the respective site and mission characters to demonstrate content mastery. They also participate in a final series of multiple-source questions presented by the Mission leader that function as the gateway to mastery of the Mission. An integrated understanding from multiple sources of information in the game is necessary in order to solve the problem of why animals are becoming sick (water contamination from fertilizer runoff – eutrophication).

All research sites and challenges are presented by characters within the game narrative. Responses to comprehension monitoring-based activities are assessed and translated into categorical game-based scores that translate to badges. Students receive immediate feedback on each task and have access to their progress in a Missions Journal. In the Missions Journal players track and then narrow their saved highlights, summaries, and images on a detective board where they can submit a hypothesis as to why animals are becoming ill. Students also select a suspect from their Suspect Board to try and guess who kidnapped Monty.

3. Research questions and Hypotheses

The current study targeted two primary research questions. First, *Do students learn science content from the game*? As a GBLE aligned with academic standards and used by educators to engage students to master those standards, it is essential that we establish that students can demonstrate learning on science outcomes. Second, *Does students' monitoring ability increase through the use of Missions with Monty, and are there differences in students' monitoring between those assigned Missions with Monty and those enrolled in a comparison condition?* Mayer (2015) presented three questions to guide GBLE research and in the current work we leveraged the media comparison question. Thus, a robust comparison condition was created for this study and administered to students through an engaging Google Forms format. The Google Forms were created to provide students with the same content included in *Missions with Monty* in an media-rich environment; however, students in the comparison condition did not receive any of the gamified features that students received in *Missions with Monty.* As such, students in the comparison condition accessed the Google Forms in the same standard format that students in *Missions with Monty* did, but they did not explore the content in a GBLE. For example, students in the comparison condition received static screenshots of the same characters from *Missions with Monty* producing dialogue in the Google Forms (See Figure 3), as opposed to dynamically interacting with them in the GBLE (e.g., navigating, clicking).



Figure 3: Screenshot of Google Form content

4. Methods

4.1 Participants

Fifth grade students from four schools in North Carolina, USA participated in the study. Students had a mean age of 10.24 years (50.4% male, 46.0% female, 1.3% other, 2.2% preferred not to disclose). Demographics included students from 67.5% White, 11.2% Black or African American, 9.8 % Hispanic or Latin American, 0.9% Native American/Pacific Islander/Alaskan Native, 4.0% two or more races, and 1.8% Asian backgrounds along with 4.3% who preferred not to disclose their backgrounds. Intact classrooms were randomly assigned to either the GBLE or Google Form comparison; there were 144 students in the treatment condition and 80 students in the comparison condition.

4.2 Measures

Before gameplay participants completed a set of instruments including demographics, interest, and a science knowledge test derived from released test items from national and international tests related to the curriculum in the game. Students were also asked questions related to their digital game preferences and history. The targeted focus of this study, however, was the potential for the *Missions with Monty* to impact science learning and metacognitive monitoring ability. Science learning was measured through an 18-item multiple-choice assessment administered both pre and post intervention. A sample knowledge item included: *A lizard's tail breaks very easily. How does this help to protect the lizard? d) The lizard can leave pieces of its tail to mark its territory; b) During a food shortage, the lizard can break off its tail and eat it; c) The lizard can leave broken pieces of tail to fool predators; or d) The lizard's tail can break off if a predator attacks*. Participants rated their confidence at the item level on a 100-point scale (See Figure 4). Bias and accuracy scores were calculated as measures of metacognitive monitoring. Positive bias scores represented overconfidence, zero no bias, and negative scores represented underconfidence. Increased accuracy was represented by scores approaching zero, the number representing perfect judgment accuracy.



Figure 4: Confidence-rating interface in the GBLE

4.3 Procedures

The study was integrated within typical classroom instruction. Before engaging the content, students in both conditions completed the series of pre-test measures. Next, students in classrooms were randomly assigned to the GBLE or Google Form comparison condition. Since the study was integrated within typical classroom instruction, students completed *Missions with Monty* or the comparison condition at the pace determined by the teacher, typically taking place over about four weeks. After completing the programs, students in both conditions completed a series of post-test measures.

5. Results

Table 1 provides descriptive information for primary variables across both conditions. Analyses first established the two conditions did not differ significantly before intervention. No significant differences were found between groups on science knowledge at pretest ($t(222) = -.824$, $p = .41$, $d = 3.69$). Also, no significant differences were found between groups on average pre monitoring bias ($t(222) = 1.84$, $p = .07$, $d = .21$). Further, no significant differences were found between groups on average pre monitoring accuracy ($t(125.46) = .30$, $p = .77$, $d = .14$).

To answer our first question, *Do students learn science content from the (Missions with Monty) game*? A dependent *t*-test was conducted to examine pre and post knowledge scores in the treatment condition. Findings indicated that students' science knowledge significantly increased after gameplay, $t(143) = -13.21$, $p < .001$. Our second question asked, *Does students' monitoring ability increase through the use of Missions with Monty, and are there differences in students' monitoring between those assigned Missions with Monty and those enrolled in a comparison condition?* Students in the treatment condition became significantly less biased towards overconfidence $t(143) = 3.85$, $p < .001$, and significantly increased the accuracy of their judgments $t(143) = 11.52$, $p < .001$. A univariate analysis next tested the differences between conditions in monitoring bias when controlling for pre monitoring bias and found no significant differences ($F = 3.13$, $p = .08$). A univariate analysis next tested the differences between conditions in monitoring accuracy after controlling for pre-monitoring accuracy and found no significant differences ($F = 1.12$, $p = .29$). Importantly, significant gains for science learning were found across conditions, $t(223) = 13.67$, $p < .001$. Findings revealed that students in both conditions demonstrated judgments that were significantly less biased towards overconfidence $t(223) = 4.44$, $p < .001$ and accuracy $t(223) = 11.81$, $p < .001$.

Table 1: Means and standard deviations

	Mean	Standard Deviation
Science Pre Knowledge Comparison	10.38	4.07
Science Pre Knowledge Treatment	10.80	3.46
Pre Monitoring Bias Comparison	.15	.23
Pre Monitoring Bias Treatment	.09	.20
Pre Monitoring Accuracy Comparison	.38	.17
Pre Monitoring Accuracy Treatment	.37	.12
Science Post Knowledge Comparison	12.80	3.32
Science Post Knowledge Treatment	13.60	2.69
Post Monitoring Bias Comparison	0.08	.17
Post Monitoring Bias Treatment	.03	.15
Post Monitoring Accuracy Comparison	.23	.18
Post Monitoring Accuracy Treatment	.25	.13

6. Implications and Future Directions

The current study is contextualized within recent research attempting to develop both conceptual knowledge and SRL skills within GBLEs. Few GBLEs have been created to develop skills in multiple academic domains such as *Missions with Monty,* thus requiring increased demands on SRL skills and for pedagogical tools necessary for appropriate scaffolds and training. Findings demonstrated that students learned science content aligned with established academic standards through *Missions with Monty* gameplay. Students also gained in their ability to monitor their comprehension as demonstrated by both decreased overconfidence bias and increased accuracy. These findings endorse the benefits for GBLEs, demonstrate the further potential for learning standards-aligned academic content in GBLEs, and support the potential for GBLEs to facilitate effective SRL.

For teaching practice these findings provide evidence justifying the use of programs such as *Missions with Monty* to support both science learning and comprehension monitoring processes. *Missions with Monty* can be used in parallel with typical classroom instruction to augment strategy instruction, content learning, and individualized feedback. The current findings add to the rather sparse literature on promoting SRL through GBLEs.

Demonstrating significant improvement in monitoring accuracy in traditional classrooms has been very challenging and typically takes distributed practice with clear feedback over a number of weeks (Foster et al., 2017; Händel et al., 2020; Nietfeld, et al., 2006;). In the current study, we were able to demonstrate significant pre to post changes in monitoring accuracy with greater efficiency, a finding not yet reported in this literature. Future research should test the benefits of practice and varied feedback models on learning, comprehension monitoring, and transfer within STEM learning environments using GBLEs. Studies should also examine how to more fully integrate GBLEs into typical classroom instruction and to test immediate and customized feedback capabilities that are not easily provided without the use of such technologies.

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Digital Games in Schools: A Qualitative Study on Teacher's Beliefs

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Abstract: Games are omnipresent for children and young people. In primary and secondary schools in Switzerland, however, games still eke out a niche existence. Topics such as Game Design, Serious Games, or the Game Culture in general offer enormous potential for teaching, and there are many ways for pupils to experience the world of games together. However, specific training programs for teachers are necessary. For many teachers, these topics are less tangible than they are for children. To develop a new curriculum for in-service teachers, this paper addresses the prerequisites for a transversal games-curriculum for primary and secondary schools in Switzerland. In this endeavour, first, links between games and the Swiss Curriculum 21 are presented. Second, recent literature on games in the school context is reviewed, and finally, interviews with teachers on their beliefs and ideas about digital games are analysed. The results show that although teachers often have a limited idea of games in the classroom, they consider the topic relevant and sometimes already use game-based approaches.

Keywords: digital games, teacher beliefs, curriculum development, game-based learning

1. Introduction

With the introduction of the new "Curriculum 21" in German-speaking Switzerland, digital media and informatics have become increasingly important. Additionally, the ZHAW James Study from 2020 (Süss et al., n.d.) states that 34% of young people in Switzerland play video games several times a week. Considering this, there is a reason to use digital games as an anchor in school. The question arises, however, whether digital games have found their way into Swiss classrooms and how teachers assess their use. This topic has hardly been researched in Switzerland, which is why a first approach to the topic via the teachers' beliefs seems appropriate to narrow down this research gap. Therefore, interviews were conducted with five teachers from primary to secondary education about their beliefs on the topic of "digital games." In addition, four concepts were selected in this paper and discussed in the interview to which references can also be made to the Swiss Curriculum 21: Serious Games, Game Design, Gamification and Game Culture.

2. Literature Review

2.1 Digital Game Concepts

2.1.1 Gamification & Serious Games

The concept of Gamification is described by Marczewski (2013). In the term's beginning, it was used in business administration and marketing, thus having no inherent connection to schools. In this context, the author provides the example of loyalty points, which can be earned when shopping in a supermarket. Werbach and Hunter (2012, p. 26) define Gamification as follows: "*the use of game elements and game-design techniques in non-game contexts*".

Although Gamification and Serious Games are related, they differ significantly in content. While Gamification puts elements from games into a different context, Serious Games are entire games. However, these games aim not only to entertain but to get the player excited about a particular learning topic (Stieglitz 2015). Serious Games are more about simulation and learning specific subject matter, while Gamification gamifies elements of a process to increase user motivation (Stieglitz 2015, 2-4).

2.1.2 Game Design

Game Design is often used as a term to describe the process of game production. While professional game development is about creating an optimised, holistic product on a large scale (Wiemker, 2021), the requirements for creating digital games in primary and secondary school can and must be scaled down. In his book "The Art of

Game Design," Jesse Schnell (2020) reasons that small games consist of 4 basic elements: Mechanics, Story, Aesthetics, and Technology. Schreiber and Braithwaite (2008) further narrow down the development of a game to two competencies: The development of *rules of a game* and the *content of a game*. Game Design can encompass various disciplines, such as developing the game idea and story, programming the game, creating visuals and sounds, and setting the rules that define a game.

With an increasing number of freely accessible learning platforms designed for use in schools, youths can develop and publish complex games themselves. It is hard to deny that game development in a school context is motivating and skill-building. This conclusion was reached by Quian and Clark (2016), who examined 137 articles on the use of digital games in the classroom in a meta-study. The best result was achieved by the game Design approach, with 13 results having a high impact on the promotion of "21st Century Skills."

2.1.3 Game Culture

Game Culture is a broad term that encompasses everything in the field of games beyond playing and developing games. For instance, the media-psychological effects of games on young people, trends, and new developments that influence us as a society play an important role.

Media-psychological effects have been discussed within school contexts for some time. For example, the meaning and effect of violence in games. Likewise, the excessive consumption and addictive behaviour of young people. The effect of advertising in computer games can also have a negative influence on young people (Fileccia et al., 2010). In addition to these often-mentioned dangers, games also provide a basis for discussion and research that can be taken up in class. For example, game preferences, genres, and the economic and socio-cultural significance of popular games. Efforts to systematically bring these topics into schools can be found, for example, in the project "Game Culture in Schools" by Buser (n.d.). Here, various phenomena are dealt with in the elective subject "Game Zone" - from the history of games to "Let's Plays", to localised game production in one's country.

Furthermore, the reflection of the young people's actions and the interaction of children with games play an important role. Here, studies such as the JAMES study of 2020 (Süss et al.) repeatedly show that video games play an important role in the everyday lives of young people. Around three-quarters of young people in Switzerland who play games spend an average of one hour on weekdays and two hours at weekends playing video games. It should be noted that game use decreases with age (from 85% among 12-year-olds to 58% among 19-year-olds), and gender plays an important role (56% of girls and 93% of boys play), while other factors such as socioeconomic status, origin, and type of school have little influence.

2.2 The Swiss "Curriculum 21"

The analysis of the Swiss "Curriculum 21" (https://v-fe.lehrplan.ch/) for primary and lower secondary education shows that numerous competencies of the curriculum can be linked to game concepts. For the paper, only competency levels in the "Media and Informatics (MI)" domain were considered. Teacher training for these competencies has only existed since 2017, and the content specification is not yet complete. Therefore, games can play an important role in topics related to MI rather than to all disciplines of STEM (Science Technology, Engineering, and Mathematics). Furthermore, MI topics are implemented differently in the Swiss cantons, either as a separate subject or integrated into other subjects. In the following we provide cross-references to the different game concepts from the previous section and the main competences from the Curriculum 21.

Important examples of a reference to "serious games / gamification" in the curriculum are the following (translated into English by the authors of the paper):
Pupils…

- …can learn and obtain information on a specific topic using given media (e.g., book, magazine, educational game, game story, website). (MI.1.2c)
- ... can use media selectively for cooperative learning. (MI.1.4d)

The entire competency area 2 "Algorithms" is suitable for embedding "Game Design" topics, since various programming concepts are described. These include sequences, loops, conditional statements, variables, and subroutines. Furthermore, the following competency levels are especially emphasised:
Pupils…

- ... can use media to create and present their work (e.g., class newspaper, class blog, radio play, video clip). (MI.1.3c)
- ... can produce media contributions with their own and other people's content, taking into account the legal framework, safety, and behavioural rules. (MI.1.3g)

A remarkable number of competency levels belong to the area of "Game Culture." Two of these are:
Pupils…

- ... can name advantages and disadvantages of direct experiences, experiences conveyed through media or virtually, and justify personal media use. (MI.1.1b)
- ... can distinguish rules and value systems of different lifeworlds, reflect on them and act accordingly (e.g., netiquette, values in virtual worlds).

2.3 Teacher Beliefs

Kirchner (2016) defines teacher beliefs as subjective, relatively stable, although experience-based changeable, partly unconscious, context-dependent cognitions of teachers. Pajares (1992, p. 324) argues that teacher conceptions are not formed during the first or second phase of teacher education; they are already formed during one's own school years, sometimes even before, and are undergoing constant change. This «apprenticeship of observation» was already described by Lortie 1975, p. 65. Pupils thus develop ideas about teaching/learning processes, subjects, etc. by observing teachers. If these students later decide to become teachers, their perceptions of teachers will also be shaped by teachers. Studies point to a direct empirical correlation between the selected advanced courses during school and the later choice of studies or profession (Kleinn et al. 2013). This also applies to future teachers. Their choice of subject often depends on their favorite subject. Computer science is not or cannot always be chosen here due to the lack of opportunities at schools. In addition, computer science is generally afflicted by many prejudices (Spieler et al. 2020). Interests, motives, and convictions play a major role in this decision.

Furthermore, various research studies have assessed teacher beliefs in relation to games (see: Allsop, Yildrim, Screpanti, 2013; Hsu et al., 2017; Cabbellos, Sanchez, Pozo, 2021; Alberola-Mulet, Iglesias-Martínez, LozanoCabezas, 2021, Belda-Medina and Calvo-Ferrer, 2022). It is evident from these contributions that teachers are open to the use of games in school or find them useful. However, lack of training opportunities (Allsop, Yildrim, Screpanti, 2013), lack of resources (Cabbellos, Sanchez, Pozo, 2021), or inflexible curriculum hinder the implementation of gaming practices in schools (Alberola-Mulet, Iglesias-Martínez, Lozano-Cabezas, 2021). In the discussion, similarities with these studies will be provided and complement with new insights from our work.

3. Method

3.1 Qualitative guided interviews

The interviews are structured with the help of a guideline (Helfferich 2011, S. 180) focused on four areas: 1) associations to "digital games" and personal attitudes, 2) experiences using Games in class, 3) children's use of games, and 4) technical terms. The following lead and control questions were subsequently defined, see Table 1.

The assumptions about teacher beliefs (see Section 2.4) helped to shape the first lead question that related to their own experiences with games in general (in school, childhood, their attitudes towards games). The second question was intended to establish the school connection to digital games, while the idea of the third and fourth questions was to open a broader picture of digital games in schools and to point out potentials or even necessities to consider games in class. Furthermore, the questions were designed so that the term "digital game" remained open initially, then further specified. This allowed respondents to come up with surprising answers (Helfferich 2011, p. 182). The terminology around games could also be concretised during the interview, leading to a broader definition, and thus increasingly specific concepts were mentioned associated with games in a broader sense.

Table 1: The lead and control questions.

	Lead Questions	Control Questions
1.	What do you associate with digital games?	1. Do you remember the first time you interacted with digital games? 2. What is your personal attitude towards games? 3. Reason for this attitude?"
2.	What opportunities/benefits do you see for the use of games in the classroom?	1. Can you imagine using digital games in the classroom? ● What games could these be? Why these games? ● What are the characteristics of a game that can be used successfully in the classroom? ● What social forms do you associate with games in the classroom? 2. How do you see the use of digital games in other subjects (others than MI)? 3. Can you think of any risks in using games in the classroom? Or disadvantages?
3.	Where do games occur in the daily lives of school children?	1. Can you name a concrete example? 2. Do games occur in the lives of all children at all? Is there a difference between boys and girls? 3. Are issues around games addressed properly in school?
4.	A slide was shown with the concepts described in 2.1.	1. What contents do you associate with these terms? 2. Are these concepts significant for the school? 3. Are there any important concepts missing?

3.2 Participants

Teachers were contacted directly by email and asked if they could participate in a short interview. Attention was paid to ensure to include teachers from different school levels, ages as well as female and male teachers to get a broad view. Knowledge regarding games in the classroom or certain expertise was not a prerequisite.

The interviews were conducted online with five teachers, see Table 2.

Table 2: Details of the teachers interviewed.

No.	Gender	Age	School type
1	female	46	Primary middle and lower school (Grade 3-6)
2	male	26	Primary middle school (Grade 5 to 6)
3	male	43	Secondary school (Grade 7-9)
4	female	57	Primary lower School (Grade 1 to 3)
5	male	32	Primary middle school (Grade 5 to 6)

3.3 Data Analysis

All online interviews were transcribed. Following Kuckartz (2018), we started the process of data analysis by applying "initial coding." This step highlighted important text passages in the transcript. Next, we used the technique of "focused coding" to identify the basis of these main categories, the subcategories. We then repeated these steps for each question.

4. Findings

4.1 Question 1: Associations to digital games & personal attitudes

The analysis showed that teachers associate positive and negative aspects with games (the main categories in bold). The **positive aspects** can be divided into three sub-categories (in italic): *Usefulness of games in class*: Classroom experiences were an important association with games. In this context, teachers mentioned the possibility of practicing learning content, individualisation of lessons, adding a fun learning element, and innovation as something new for the children to do collaboratively. *Specific game elements:* Teacher 2 introduced the concept of "Gamification" or the link to some sort of Learning Management System (LMS) where

"students have to get started, take on a role, i.e., a character and have to complete a learning path or reach the next level and that motivates them a bit intrinsically." The competitive aspect was also mentioned because of the possibility of measuring oneself against other classmates, e.g., in levels or collecting gadgets. Teacher 5 uses the expression "reward system." For example, when someone finishes an exercise in class, they play a game on their tablet. This type of reward was also mentioned by another teacher, i.e., playing as a reward for something achieved or to keep busy at the semester's end (Teacher 4). The third category includes g*ames as leisure time* in association with fun and entertainment (Teacher 3, 5).

Negative mentions were also related to *games in school* associated with effort because the children need equipment and knowledge about the platform (Teacher 4). She mentioned at the beginning of the interview that she does not find games appropriate in class at all. *Games & Leisure time*: In leisure time, games are portrayed as "time wasters" and as an escape from reality (Teacher 5).

This interesting comment by Respondent 5 regarding stigmatisation and old-fashioned stereotypes in relation to games can be seen as **neutral**: "*For a long time, games had a negative connotation in the media because of school shootings and their connections to shooter games. Today it's different. It's no longer just the stereotype of the boring fat guy in his mid or early 30s sitting at home playing these games. Today it ranges from young to old, man and woman*."

The control questions asked about their **own attitudes towards games** and where or when they had first **contact with games**. The youngest respondent, Teacher 2, mentioned that games were a topic in his own school days. However, the non-cooperative nature of this experience was highlighted in this context. Two of the respondents (Teachers 2, 3) mentioned they were exposed to certain tools such as "*Kahoot*" or "*Quizlet Life*" during their teacher education. *Gaming attitude:* Teachers 2 and 5 expressed a positive attitude, while others expressed themselves very negatively towards games. Teacher 2 played a lot as a teenager and even compares games to a "form of art," although he rarely plays games today. Teacher 5 tried different consoles in his childhood (e.g., Game Boy, PlayStation) but describes the games children play today as "trash," although he understands student fascination with them. Teacher 1 says she is not a "game freak" and only plays games to relax. Teacher 3 also says that he does not play digital games. Moreover, he describes games as a waste of time. He understands the purpose of learning games but argues they lack importance. In addition, Teachers 3 and 4 mentioned their experiences with their own children. Negative experiences were reported by Teacher 4 (e.g., games have taken up too much of my children's time, a lot of time is spent indoors, lack of social contact) as well as positive ones by Teacher 3: "*I can rediscover this world of games through my son*."

4.2 Question 2: Experiences in using Games in Class

The second leading question started with **possibilities, even advantages, of games** in class. Answers can be divided into four subcategories: *to increase motivation*: Here, Teacher 2 mentioned that games motivate children, having them engage with something they otherwise would not bother with. The children are allowed to bring something of their private lives to school. Teacher 3 notices that there are more and more children playing games, and teachers can take advantage of that. *To enhance the learning effect*: Here, possibilities of self-directed or individualised learning were mentioned; that it also trains digital application skills, and that children who play are generally more competent with computers (Teacher 2) or that topics can be repeated in a playful way (Teacher 4). *New possibilities through games*: Games could have a balancing factor and create a common basis (Teacher 2). Games appeal to children on a different level (e.g., visually), and sometimes, children who are otherwise reserved can pass on their knowledge of games (Teacher 3). Teacher 1 refers to the fact that children also get immediate feedback on their learning. *Promoting social competencies*: Here, a social component was generally emphasised (Teacher 5), and when students play against each other, they also learn how to deal with frustration (Teacher 1).

At this point, Teacher 3, who was initially very negative about digital games, describes the enormous potential of games in general in the classroom: "*In my opinion, playing is a very natural human characteristic. As a child, we started playing, and then at some point, we were told we can't play anymore, we must learn now [...]. There is a lot of creativity in it. All games where you can create something, where you can build and design something, have a huge potential. Not in the sense that you passively do something, but that you drive the action or design the action yourself and then, of course, also must live with the consequences. And that has a very big learning effect.*"

Regarding games or playful applications teachers already **used in the classroom**, some specific tools could be gathered: quiz apps like *Kahoot!* (kahoot.it) and *Quizlet* (quizlet.com) by Teachers 2, 3, 5; *Anton* (anton.app) with playful elements by Teachers 1, 3, 4, and *learning apps* (learningapps.org) by Teacher 5. Teacher 1 mentions the game *Conni* (conni.de/apps), which is very much geared towards girls. Teacher 3 mentions two *simulation games: PostFinance* and *PearUp,* to build your own start-up. Teacher 5 mentions the use of the *Unreal Engine* (unrealengine.com) for the purpose of Game Design and that his students are engaged by designing own characters and worlds.
For the question of what **requirements, a game** needs to be used in the classroom, the following subcategories could be identified: *Recommendation/certification from authority:* According to Teacher 2, there should be recommendations for appropriate, usable games. Currently, according to Teacher 1, one must try out whether a game fits or not, which can be time-consuming. *Thematic fit:* Teacher 3 said that the game must be thematically suited to the current subject matter and should also train transversal competencies. It must relate to the students' lives or the topic they are working on. Furthermore, it must be mature and add value to the lesson. Teacher 1 continues that there are learning programmes already installed on the school's iPads, but many are without educational purpose. *Simple/self-explanatory:* Teachers 4 and 5 urge that games must be simple and self-explanatory. It needs to be accessible for children to start quickly. Accompanying resources were additionally mentioned by Teacher 2. The game must not require too much time, money, and hardware/tools to be usable (Teacher 5). *Appealing design:* According to Teacher 3, the game must be sustainable, appealing, and not have any bugs.

Regarding the **social form of games**, the teachers agreed that this should mostly be done collaboratively at school but could be accomplished individually. Also, competitive games are allowed.

Regarding the **risks or disadvantages of games in the classroom**, the following subcategories can be defined: *Purpose*: Teacher 2 describes that many learning games require a certain amount of prior knowledge to be successful. Consequently, if children are bad at a subject, Gamification elements will not help them or can even be demotivating. Teacher 5 notes that it is often difficult to see the learning outcome and that games can be manipulated by children. Teacher 1 argues similarly (“too confusing”) and that there are too many ineffective games. *Addiction/isolation* (also related to parental acceptance): Teacher 2 sees addiction as an important topic but associates this more with media in general. Teacher 3 points to the high addiction potential of children who usually do not play games at home. Teachers 3 and 5 have already been confronted by concerned parents in this context. Teacher 1 describes that she often perceives isolation through games. The children talk less to each other and interact less (games in a form of a "silencer"). *Effort*: In addition to resources, time, and costs (Teachers 2, 4, 5), a certain amount of control was also mentioned so that children do not lose themselves in games (Teacher 1). *Data protection*: Teacher 2 sees the risk of children's personal data being used, especially when the programs originate from non-governmental organisations.

4.3 Question 3: Games as part of the children's everyday life

Teachers 1, 2, 3, and 5 agree that **games play an important role for children**. The subcategory identifies where games are a topic: *At home*: Teacher 1 reports that children play many games, but she knows little about how their parents regulate this. With others, she feels that playing is not an issue at all. Teacher 4 describes those children in lower grades play less (most of them do not have their own mobile phones yet). Teachers 2 and 5 report that they notice children schedule to play together at home. *School breaks*: According to Teacher 1, many children have trouble detaching themselves from the iPad when switching between that and analog exercises. Between breaks or when changing lessons, many children start playing on the iPad. Teacher 3 reports a similar situation *“Every 5-minute break is used for surfing or playing games online. In some classes, this is very characteristic. When I ask everyone to stop playing at the beginning of the lesson, they get very frustrated, and the lesson starts negatively”*. Teacher 5 reports that he often must interrupt conversations about games post-break. This happens mainly in the morning when they have played together the day before or in the afternoon when they plan to play together again. Teacher 2 also reports he heard the following statements: "*Yesterday you stayed online late,*" "*You play a lot*" (both with positive and negative connotations), but also "*You are addicted*" (as an accusation).

One specific question regarded the **difference between girls and boys** in playing games. Teacher 2 mentions that, in his opinion, more girls play games on tablets or mobile phones. Teacher 3 raises that for girls, it is more about social media apps like *TikTok* or *Instagram*. Teacher 4 states that although girls talk less about games at

school, they play equally at home. This is also mentioned by Teacher 5, who adds that many girls also have their own game consoles at home.

With our future goal being the development of a new games' curriculum, it was particularly interesting to find out whether teachers think **games should be a topic in school**. Teachers were divided in opinion here. Teacher 1 reports a social worker at their school who discusses the topic already with the children. Teachers 2, 3, and 4 believed the school should treat the topic of "games" more effectively. According to Teacher 2, the topic of "addiction" is addressed too quickly (e.g., by the school's remedial teacher) and not differentiated enough. He himself tries to address games in school and wants pupils to ask him about games. Teacher 3 thinks it is often attributed to the children, assuming they know about smartphones and games. However, in his opinion, they know little about the dangers (e.g., hidden agendas of the game industry, advertising issues). Teacher 4 thinks that the topic also belongs in school, but it is mainly the parents who should educate the children about games. Teacher 5 also sees both the school and the parents as responsible.

4.4 Question 4: Knowledge of game concepts

In general, most of the terms shown were unknown to the teachers. Concerning **Game Culture**, Teachers 2 and 3 picked up on issues from the previous discussion points, such as games as part of identity, anonymity in games, and addressing stereotypical beliefs.

Game Design was explained by Teachers 1, 4, and 5 from the perspective of game development companies (and their hidden agendas). Teacher 2 mentioned the development environment *Scratch* and considerations about game ideas to find out how games are designed. Teacher 3 reported successfully prototyping his app development course.

Game-based Learning has been interpreted by Teacher 2 and 5 as a universal concept.

Gamification is noted as something digital by Teachers 4 and 5. Teacher 3 describes it as the motivation that keeps students online, like embellishing their avatar when they have done certain things. Teacher 2 describes Gamification as making a game out of something that is not a game initially.

For **Serious Games**, Teacher 2 gives the example of simulation games. Teacher 5 says that it is a kind of "organic label" for games.

5. Discussion

The constructive nature of the questions (see Section 3.1) led to the result that teachers initially had a limited idea of digital games and may not even see them in the context of school (e.g., Teacher 3, 5). However, they recognise the importance of games in children's lives and thus the role of school in addressing these issues. Very often it was mentioned in this context that the game must serve a purpose for the school, and at the same time, the effort for introducing the game in class should be kept very low. These technical and pedagogical efforts were also reported in the findings of Belda-Medina and Calvo-Ferrer (2022).

Moreover, some of the presented findings can also be replicated in other studies: For example, the evaluation shows that teachers who played digital games in their childhood also have a more positive attitude towards games today and greater knowledge in the field. This was also reported by Cabbellos, Sanchez, and Pozo (2021). Knowledge about games can lead to a better evaluation of potential learning aspects that are not recognised by teachers who use fewer games. The more teachers play games, the more positive their assessments are. This is also shown in the studies by Sánchez-Mena et al. (2017, 2019). Similar studies showed the same trend for the intention to use (Bourgonjon et al., 2013; de Grove et al., 2012). This could be partially adapted for our study. Belda-Medina and Calvo-Ferrer (2022) were also able to show that a huge number of games are generally used by teachers regardless of aptitude. According to the teachers, the low effort and thematic components are particularly important for using games in the classroom. A new implication of this study is the influence of one's own children: Teacher 4 was, in her opinion, strongly negatively influenced by her children who play a lot, while teacher 3 sees the possibility of games being viewed more positively by his son. Furthermore, we see teachers' observations of how children talk about games at break time, how they engage in play or how much games should be a topic at school are also new insights. Even when specific subjects or teachers in schools are designated for the topic of media, teachers often report feeling that the topic is not sufficiently addressed.

At the same time, some new aspects were raised in our interviews that have not been reported before. For example, teachers are aware that games are not only played by a certain group of people (see stereotypes) but are everywhere, and even if they do not see games as beneficial for their teaching, they are an omnipresent topic anyway, for example during breaks or in pupils' leisure time. As an additional comment, Teacher 2 noted that girls should be introduced to games more and games should become normal. Interestingly, all teachers reported that girls and boys spent the same time playing games, but girls did not talk about games as much at school. This is consistent with previous studies by the author where girls did not see themselves as "gamers" (Spieler et al., 2020). Further research is needed to explore the pre-existing construct of games and how they might act as an encouraging factor or a barrier when the teacher mentions a "learning game". Another conclusion from this study is the influence of one's own children, which could also have an impact on teacher beliefs: Teacher 4 was, in her opinion, strongly negatively influenced by her children who play a lot, while Teacher 3 sees the possibility of games being viewed more positively by his son. Furthermore, teachers' observations of how children talk about games at break time and insights on if at all games should be a topic at school are new insights. Even if specific units or teachers are designated to MI, teachers report that the topic is certainly not sufficiently covered now, indicating the potential for future training.

6. Conclusion & Outlook

In this study, the beliefs of five teachers regarding digital games were analysed and compared with existing studies. From the interviews, it emerges that teachers need to be addressed on different levels. On the one hand, prejudices must be reduced in advance (e.g., with the involvement of parents, definitions of concepts, and general benefits), best practice examples and use cases must be highlighted (when do games make sense at all), and games must be perceived as a very comprehensive topic and as an opportunity to be used for all teachers. If questions of data protection, usefulness, and possibilities, or even necessities are clarified in advance, it can become an exciting teacher training for all teachers and not only for those who have already had positive experiences with games.

Based on these initial results, we will investigate the current appearance of games in teacher education at Swiss universities. Based on these surveys and further evaluations, a new curriculum for digital games in teacher education will be developed to be used in MI or interdisciplinary.

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Training team Creativity with Lego Serious Play: Upside and Downside of team Diversity

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Abstract: We trained 40 teams using Lego Serious Play (LSP), a facilitated workshop method in which the aspects of visualization, commitment, fun and shared storytelling are used. LSP improves open and participatory communication, collaborative learning and intuitive imagination and reduced 'free ridership' in innovation teams; it was easier to achieve a 'train of thought' or 'flow' within a team. LSP is a promising creativity method, although its efficacy is influenced by conditions. Teams can enhance or disrupt creative performance. Different mindsets within creative teams may lead to a broader pallet of new perspectives in the ideation phase of innovation in which divergent thinking is important to explore novel viewpoints. However, diversity may lead to relationship conflicts in a team. We address the dilemma of achieving synergistic benefits from team diversity while managing negative interpersonal tensions between heterogeneous team members in relation to motivational aspects and team climate and summarize this in a significant three-path mediation model. We found a highly significant path with team performance of team diversity, commitment, and 'voice' (i.e. the extent to which team members are encouraged to express their views in the team). Team diversity has a potentially upside effect on creative performance, as well as a practical downside effect: it can be a source of interpersonal tension and intergroup biases and consequently less commitment leading to a less open team climate, resulting in lower team performance.

Keywords: Team creativity; personality; team diversity; commitment; team climate

1. Introduction

1.1 Team creativity

Creativity is an important 21st century skill (World Economic Forum, 2020). It is defined as the generation of original and appropriate ideas; originality requires divergent thinking, whereas appropriate ideas convergent thinking (Baas et al., 2015). Creativity is determined by cognitive, emotional and neural processes. Cognitive processes, include cognitive flexibility and cognitive persistence; mood and motivational states influence creativity (Nijstad et al., 2010). Cognitive flexibility, divergent thinking or idea originality is operationalized as the number of new viewpoints whereas cognitive persistence as convergent thinking, detailing ideas into greater accuracy. Baas et al. (2008) researched motivational or emotional aspects of creativity, such as happiness, joy or dislikes. Negative emotions reduce divergent and flexible thinking, although the effects depend upon circumstances.

Team creativity is determined by characteristics of individual team members, as well as the combination of traits of team members (Gilson et al., 2015). In teams, two or more individuals socially interact (face-to-face or increasingly, virtually) and face a certain degree of interdependence regarding executing tasks and processes (Kozlowski & Ilgen, 2006). Adaptability of team members, interpersonal communication and coordination of activities are drivers of team performance (Mathieu et al., 2014). Therefore, it is important to involve members in a team who can conduct these behaviors. Won et al. (2014) found that synchronized nonverbal behavior leads to greater team creativity. Team composition affects team creativity, which in turn promotes innovation implementation depending on the team's climate for innovation. (Somech & Drach-Zahavy, 2013). Team creativity can be defined in terms of outcomes or processes. Team creative outcome concerns the production of new and useful ideas of products and services, whereas creativity as a process concerns the journey toward possibly producing creative outcomes through the collaborating behaviorally, cognitively, and emotionally (Gilson & Shalley, 2004; Gilson et al., 2015). Creative processes are an important ingredient for creative outcomes. In this study we relate to the distribution of personal attributes among interdependent team members, in particular we focus on team members' heterogeneity in terms of personal behavioral preferences.

1.2 Team diversity

Team diversity has multiple dimensions, e.g. –gender, age, race, religion, or personality, attitudes, and values, coined as "diversity mindsets"; researchers emphasize the importance to consider differences that may not be readily visible: differences in mindsets (Knippenberg & Schippers, 2007).

Diversity can potentially boost team performance. Team diversity may stimulate team creativity because the team members are inclined to introduce different or divergent perspectives and a variety of knowledge, skills, abilities that consequently may lead to more innovative ideas (Wang et al., 2016; De Dreu et al., 2008**)**. However, there is also a downside of team diversity: teams are often unable to benefit from their diversity (Homan et al., 2007). Despite the growing interest in team diversity, little is known about the mechanisms through which personality traits affect team climate for creativity and creative team performance. This research attempts to fill this gap. Understanding team processes is vital to improve team performance outcomes in organizations (Klonek et al., 2019). Team diversity it is a double-edged sword: it can enhance as well as disrupt creative team performance (Joshi & Roh, 2009). On the one hand, diversity may lead to task-related disputes coined as 'creative friction' through which within the team new perspectives can be developed. Diversity of viewpoints is beneficial for nonroutine tasks associated with divergent thinking tasks of the fuzzy front end of innovation: exploration. Here, imagination and exploring unusual out-of-the-box ideas are essential. On the other hand, diversity may lead to relationship conflicts in a team, or to a lower level of commitment and psychological safety which may complicate the implementation of innovative projects.

Exploitation activities require less team diversity: routinization, refining the best options, elimination and clear decision making to achieve efficiency in performance of more repetitive tasks. Most teams perform tasks with both explorative and exploitative components and face tensions between these activities (Lavie et al., 2010). Although a certain level of team diversity is beneficial, team members may also respond negatively to dissimilar others resulting in reduced team performance (van Knippenberg et al., 2004). It is thus essential for teams to ensure a creative team climate in which it is safe to participate in the decision-making and that encourages team members to introduce new ideas or opinion: a team climate of psychological safety, voice, and participative decision making; a supportive climate makes effective use of the potential if the group (Carson et al., 2007; De Dreu et al., 2008; Edmonson, 1999; Muehlfeld et al., 2011). They conclude that it is an interesting research avenue to acquire a better understanding of harvesting potential benefits of diversity of mindsets within teams (Knippenberg & Schippers, 2007).

We address this dilemma of achieving synergistic benefits from team diversity while managing team processes and negative interpersonal tensions between heterogeneous team members in relation with motivational aspects and team climate. Our research question is: *What are the upside and downside effects of team diversity related to team creative performance when training team creativity with Lego Serious Play?*

1.3 1.3 Lego Serious Play

Lego Serious Play®[1] (LSP) is a facilitated workshop method in which the aspects of visualization, commitment, fun and storytelling are combined. LSP is a good example of challenge-based learning. In LSP, participants generate new solutions to wicked problems by creating symbolic and metaphorical models. They build these models with specific Lego Serious Play bricks and discuss individual and team metaphors through storytelling with the aim to enhance creativity in ideation exercises and shared understanding of the implementation aspects. This process coined as *shared storytelling* (Kristiansen & Rasmussen, 2014; Schulz et al., 2015).

LSP is a tool-kit and method for collaborative creativity. In contrast to usual brainstorming methods as mind mapping, or the 'six thinking hats' method. It offers the advantages of tangibility and unpredictability: the tangible shapes, sizes and colors of the Lego bricks offer infinite unpredictable combinations (Al-Jayyousi & Durugbo, 2020). In addition, it has the advantages of open and participatory communication, collaborative learning, and incites intuitive imagination (Simon et al., 2020). LSP is a method that facilitates creative problem-solving and team building (Al Jayyousi & Durugbo, 2020). It involves all participants equally without hierarchical constraints. This creates an open team environment that stimulates conversation and discussion and avoids 'free ridership' in innovation teams (McCusker, 2020). Because of these factors, it is easier to achieve a 'train of thought' or 'flow' within a team, i.e. building upon each other's ideas, known as interactional synchrony (Zenk et al., 2021). Furthermore, LSP stimulates commitment to the team, resulting in active participation in the decision-making. According to Primus & Jiang (2019), LSP facilitates developing novel and surprising solutions to problems. Zenk et al., 2021 conclude that LSP improves the creative team output.

LSP is a form of a serious game, that uses constructionism (converting abstract ideas into visible and tangible metaphors), hand-mind connection (building on the complex interplay between the hands and the brain), and

[1] LEGO Serious Play is a registered trademark of the LEGO® company.

playful fun to stimulate imagination (Frick et al., 2015). The LSP method is based on four essential steps (1) introducing a wicked challenge to the participants by a facilitator; (2) constructing potential answers to the challenge making metaphoric models with LEGO bricks individually. While building their models, participants assign a meaning to them and develop a story covering the meaning. In doing so, they construct new knowledge; (3) sharing stories and the meanings assigned to the models with each other; (4) reflecting on what is heard and seen in the models (Frick et al., 2015).

Our LSP serious games consisted of the following phases: after the introduction of game and assignment, the participants conducted a warming-up skills exercise to familiarize themselves with the Lego bricks. After this, we introduced the creative task of the serious game: to develop an innovative and feasible solution to the accessibility of education for all boys and girls in low-income countries. This task is inspired by the UN Sustainable Development Goal # 4 (Education for all). After this, participants silently developed individual solution metaphors and explained these individual solutions to each other. In the next phase, they combined the best elements of the individual models, and developed a shared solution. To increase reality and test robustness of the team solution, in the last phase of our LSP-process, the team added internal and external relationships and discussed the consequences through discussing 'what-if' questions. These indicated whether relationships were flexible or inflexible, and to what extent the relationships were vital to the solution (of major or minor importance). In their 'what-if' discussion, they considered what would happen to the feasibility of the solution if major disruptions would occur, e.g. climate change, corruption, war, famine. To what extend were the model to be adjusted when major external circumstances would occur? In Figures 2 and 3, we illustrate an LSP-workshop.



Figure 2: Example of solution of an LSP-workshop



Figure3: Visualization of shared storytelling

Source: own research

2. Theory and hypotheses

2.1 Team diversity and commitment

People can be intrinsically motivated toward a task (getting satisfaction or joy), or extrinsically motivated (based on external pressures such as deadlines or positive motivators such as incentives and recognition). Both types of motivation matter (Amabile & Pratt, 2016). In heterogeneous teams, the personal preferences of team members differ substantially. They possess unique and indispensable information, knowledge, and perspectives relevant to the team tasks. When team members have to deal with different preferences and opinions of their colleagues, they may be inspired by one another, if they are competent to deal with diversity, or feel irritated, if they cannot handle the differences (Wang et al, 2016). Dealing with diversity is more complicated because people need to be motivated to spend sufficient energy in the collaboration with their team members. Diverse teams tend to be divided in subgroups or faultlines; a categorization of 'we' and 'them'. This division usually has a negative impact on team processes and performance (Homan et al., 2007). Dealing effectively with team diversity requires more communication skills and team coordination. The intrinsic motivation or engagement to participate in the team may decrease if individual contributions are not identifiable in team tasks. An individual's reluctance to contribute to the group product even when the individual contributions are identifiable and evaluable is called free riding behavior. Other team members may feel exploited by free riding teammates, and wait to see how much effort others will put into a group before they put any in (Hütter & Diehl, 2011). We can conclude that team diversity complicates communication and expect:

H1: Team diversity is related to a lower commitment to the team.

2.2 Commitment and a supportive team climate

Commitment is a strong predictor of creative performance (Gilson & Shalley, 2004; Zhang & Bartol, 2010). Creative process engagement is positively related to the so-called 'voice' aspect of a supportive climate (Yang et al., 2021). Voice is defined as the extent to which a team member is encouraged to express his or her views to other team members (Yang et al., 2021). Engagement of team members in creative processes involves behavioral, cognitive, and emotional efforts. Only committed individual team members are willing to spend these efforts to a team (Yang et al., 2021). Engagement in creative processes will be reduced when individuals perceive other team members as threatening (Gilson & Shalley, 2004). Team members are interdependent upon each other to fulfill the team's aims. They rely on fruitful relationships with the others, or on the degree to which team members can count on each other to achieve important outcomes. Interdependency concerns the task-component of a team collaboration, whereas commitment the psychological assessment of that interdependence (Le & Agnew, 2003). Commitment can be strengthened by the amount of satisfaction that one derives from a relationship and can be weakened by possible alternatives to that relationship (Le & Agnew, 2003). Commitment is an essential ingredient of a supportive team climate; therefore, we postulate:
H2: Commitment to a team is related to a supportive team climate, i.e. support for raising your voice.

2.3 Supportive team climate and team performance

A supportive team climate may contribute to team creative performance because team members are able and committed to contribute to the team through expressing their views to the team (Gilson & Shalley, 2004; Yang et al., 2021). Such a team climate enables out-of-the-box thinking, creativity, and daring to take risks. It motivates engagement and involvement in exploratory and exploitative learning, resulting in more creative team performance (Edmondson & Lei, 2014). In a supportive team climate, team members believe that their fellow team members share goals and aims; they are allowed to take risks, openly exchange information, and consequently dare to introduce new viewpoints. There is tolerance, or even encouragement of taking risks, trying new approaches, and participate actively in creative problem solving (Gilson & Shalley, 2004; Edmondson, 1999). Voice, in which extent team members are able and willing to express their views, is a key driver for promoting creative performance because of higher creative process engagement (Yang et al., 2021). Voice is associated with social interaction, facilitation, and participative behaviors in teams through increased engagement and involvement to the team tasks. Therefore, we propose:
H3: A supportive team climate (i.e. voice) leads to higher creative team performance.

Our research model is visualized in Figure 4.

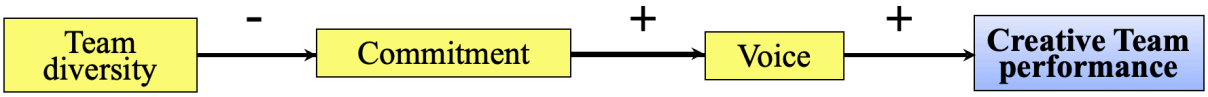


Figure 4 : hypothesized path model between team diversity and creative team performance

3. Research methodology

3.1 Data collection

In the period 2018 – 2022, we gathered data by means of web questionnaires via Qualtrics software two weeks before and direct after the creativity training. In an ex-ante questionnaire, respondents assessed their mindsets, in an ex-post questionnaire they scored the creative team performance. The study was conducted with 40 teams of 172 (under) graduate students and teachers from Universities in Groningen, Twente, Tilburg and Brabant (the Netherlands) in the period 2018–2012. The research took place in the context of skills and training courses that were a part of the study programs. The standardized team assignment consisted of an analytical and an innovative component. After the assignment, the students filled in an evaluative questionnaire concerning the team climate and the team performance. Participants were, on average, 25.5 years old.; 61.0% had a Dutch background, 12.4% were German, and 26.6% had 34 other nationalities. Teams had, on average, 4 members, ranging from three to six. In total, 51.4% male and 48.6% females participated in the research.

3.2 Measures

Of all the constructs we will list the dimensions, example items, and their Cronbach's alphas insofar applicable.

Team diversity. We observe team diversity by examining differences in mindsets within a team through a self-report inventory of behavioral preferences: the Insights Discovery Preference Evaluator (IDPE), based on Carl

Jung's theory on personality and behavioral styles (Jacobi, 1973). IDPE integrates task versus relationship orientation with introspective or extroverted attitudes. IDPE distinguishes four behavioral styles or colors (see Figure 5): 'Cool Blue' (Introvert Thinking), 'Fiery Red' (Extravert Thinking), 'Earth Green' (Introvert Feeling) and 'Sunshine Yellow' (Extravert Feeling). A Cool Blue mindset is associated with conscientiousness, precise decision-making, strict alignment of priorities, and consistency of methods. In contrast, a Sunshine Yellow mindset prioritizes flexibility, openness to experience, and idea networking. People with high Fiery Red scores focus on achieving results, and quick action. In contrast to Fiery Red, people with high scores on Earth Green emphasize reliability, cohesion within the team, a positive atmosphere, mutual respect and authenticity. Different tasks demand for different mindset characteristics. The results the IDPE-questionnaire are four colors scores. Our measure of team diversity was the average of the standard deviation scores of the team members.

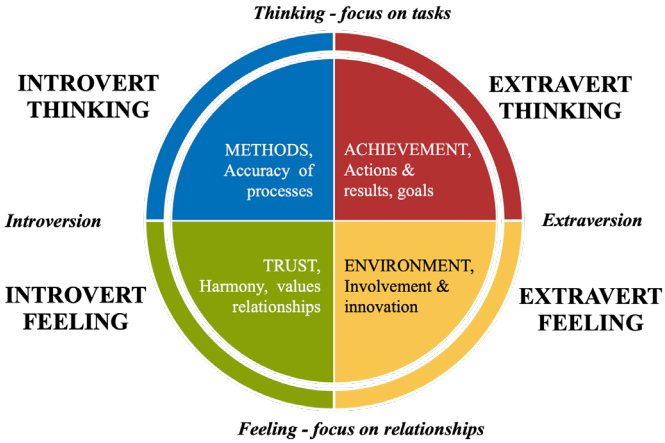


Figure 5: Four different mindsets of the Insights Discovery Preference Inventory

Team climate. We examine a team climate by the scale of 'voice'. This scale exists of four 5-points Likert items: My team members were encouraged to speak up to test assumptions about discussed issues; As a member of this team, I have a real say in how this team carries out its work; Everyone on this team has a chance to participate and provide input; My team supports everyone actively participating in decision making; α = .84 (Carson et al., 2007).

Team performance. Our outcome variable consists of two items derived from Pearce & Sims (2002): "The team faced new problems effectively" and "The team did a very good job". α = .70.

Commitment. We asked the participants to rate their commitment on a 0-100% scale.

4. Results

4.1 Descriptive statistics

In the bivariate correlations, we find a negative relation between team diversity and commitment. Commitment is positively associated with 'voice' and team performance. Voice is strongly related to performance. In Table 1, we report the descriptive statistics.

Table 1: Correlations Among the Variables, Means and Standard Deviations

	M	*SD*	1	2	3	4	5
1. Gender[a]	1.44	.50					
2. Age	24.43	5.27	.07				
3. Team diversity	1.13	.33	-.05	-.04			
4. Commitment	73.33	23.00	.11	.00	-.34*		
5. Voice	5.80	.96	-.01	-.14	-.15	.52***	
6. Team performance	5.80	1.07	-.02	-.08	-.09	.41***	.59***

[a] 1 = male; 2 = female *Note.* The correlations with team diversity are calculated at the team level (n = 40) and those among the other variables at the individual level (n = 172). *p < .05; ***p < .001.

4.2 Multivariate regressions

The results of the multilevel analyses are presented in Table 2. They show that - corrected for gender and age - color diversity is significantly related to commitment. The means that Hypothesis 1 is supported: indeed, team diversity leads to lower commitment to the team.

In addition, the relationship between commitment and 'voice' - corrected for gender, age and color diversity - is significant, supporting Hypothesis 2: commitment to a team can be associated with a supportive team climate with voice. At last, 'voice' and commitment - corrected for all variables - are significantly related to creative team performance. This implies that also Hypothesis 3 is supported: a supportive team climate (i.e. voice) leads to higher creative team performance.

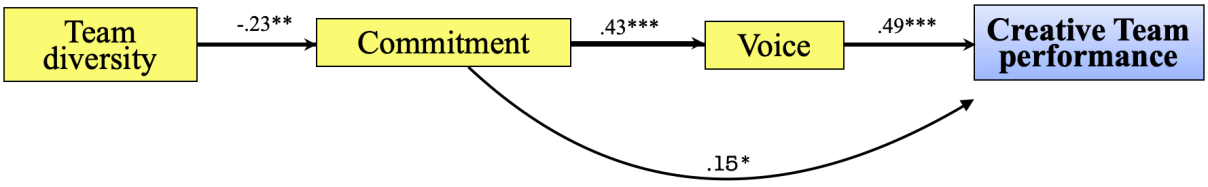
Table 2: Results of Multilevel Analyses

Independent variables	Commitment	Voice	Team performance[a]
Gender[a]	.13	-.10	-.02
Age	-.07	-.10	-.05
Team diversity	-.23**	.05	.01
Commitment		.43***	.15*
Voice			.49***
-2 Restricted log	669.81	561.59	425.88

[a] 1 = male; 2 = female. *Note.* Presented are standardized estimates. Team diversity is a team level variable and the other variables are at the individual level. *p < .05; **p < .01; ***p < .001.

We found a highly significant path model between team diversity, commitment, 'voice' and team performance. A healthy team climate, in which team members are encouraged to contribute (high 'voice' in the team) is a strong predictor for team performance. High commitment of the team members enables a team climate with high 'voice'. However, team diversity can be negatively associated with commitment to the team. We conclude that although team diversity might be needed to generate new perspectives, diversity also might reduce team performance because of a possible negative effect on individual commitment to the team's processes and outcomes.

The main results are graphically presented in the path model in Figure 6. This is a three-path mediation model describing the mediation between team diversity and team performance through commitment and 'voice' in a series. Taylor et al., 2008, indicated that such a model is supported when: (1) the relationship between the independent variable and the first moderator is significant, (2) the relationship between the first and the second moderator, while controlling for X, is significant, and (3) the relationship between the second moderator and the dependent variable, while controlling for the independent variable and the first moderator, is significant. The results in Table 2 show that our three-path mediation model is supported. We concluded that the relationship between team diversity and team performance is mediated by commitment and 'voice' in a series.



Note: ***p<0.001; **p< 0.01; *p<0.05

Figure 6: Path model Team diversity – commitment-voice and team performance

5. Discussion

Working with people with different mindsets in a team is more difficult than working with similar people. Even some refer to "Surrounded by idiots" when collaborating with team members who have different personal preferences or personalities (Erikson, 2019). Therefore, teams should be aware of the upside and downside aspects of their team's diversity and understand the impact of it. They should recognize differences, connect and engage with each other, even if this might be difficult. Identifying and discussing differences in a team might be challenging, but can play an important role in handling the diversity in a team more effectively (Van Knippenberg & Van Ginkel, 2021). In our research, we found a highly significant path between team diversity,

commitment, 'voice' and team performance. Although team diversity can have an upside effect on creative performance due to a broader pallet of new perspectives in the ideation phase of innovation, team diversity involves a downside effect: it can be a source of interpersonal tension and intergroup biases and consequently lack of commitment leading to a less open team climate resulting in lower team performance (van Knippenberg et al., 2004).

Team diversity of mindsets complicates communication between team members and consequently the probability of conflict and turnover is higher (Goerzen & Beamish, 2005). In general, people tend to favor, or trust similar others and are more willing to cooperative with them (Nijstad, 2009). As a consequence, members of diverse team trust each other less and are less willing to cooperate closely, and tend to have more conflicts. It can be expected that heterogenous teams have lower team performance.

Working with storytelling and using the visual elements of LSP had a positive effect on the commitment, motivation, and fun of the participants. Shared storytelling is an interesting method to engage all team members and create a supportive team climate. During the LSP-sessions, we identified six important success factors: a suitable assignment, team size, not too dominant team members, active facilitation, team tenure, and sufficient time. First, a creativity assignment should be wicked i.e. not too narrowly defined in line with a paradox for team creativity: the tension between freedom and constraint (Rosso, 2014). On one hand, creative teams want not to be limited in their creativity thinking. On the other hand, those limitations can provide helpful boundaries to provoke and structure the collective creative process (Rosso, 2014). Second, team size has contradictory effects on team creative performance. On the one hand, if knowledge is combined effectively, a larger team size may result in more team innovation (Peltokorpi & Hasu, 2014). However, larger teams might complicate social processes within the team, and may result in more frictions between team members, a less-supportive team climate and less individual commitment to the team. When focusing on *shared* storytelling, a team should have sufficient team members to explain and reflect with. In our research, the ideal team size was 4 people. In larger teams, we noticed more faultlines and less 'team flow' resulting in lower team creativity. Third, when members within teams played a too-dominant role, commitment of other team members tended to be lower, and the 'voice' within the team tended to be less resulting in less creative team performance. Fourth, facilitators play an important role at the reflection phase of LSP. They are expected to ask in-depth questions to the team regarding the team processes and stimulate team reflexivity. This implies that a facilitator should be able to coach team processes adequately, including non-verbal communication. Fifth, team tenure impacts a supportive team climate and consequently team performance; when team members are familiar with one another, they dare to contribute easier to the team and tend to be more committed after having developed more social capital within the team (Hu & Randel, 2014). Last, sufficient time for an LSP-trajectory is important; LSP consists of various phases of build-explain and discuss metaphors. Limited time available for the entire cycle of LSP-steps, resulting in time pressure tend to reduce creative team performance (Chirumbolo et al., 2004).

6. Conclusion, contribution, practical implications and limitations

We trained the 21st century skills critical thinking, creativity, collaboration, and communication in a serious game challenge-based learning setting. We configured teams with varying diversity of mindsets based on IDPE: we distinguished teams with low and high diversity. The team members gave each other direct feedback of their ideas with a high level of interactivity. We used Lego Serious Play, a facilitated workshop method in which the aspects of visualization, commitment, fun and shared storytelling are used. The teams generated new solutions by creating joint symbolic and metaphorical models. In the LSP-processes, we noticed as expected open and participatory communication, collaborative learning and intuitive imagination. In general, LSP reduced 'free ridership' in innovation teams; it was easier to achieve a 'train of thought' or 'flow' within a team. Therefore we conclude, LSP is a promising creativity method, although its efficacy is influenced by conditions: (1) a wicked challenge; (2) an adequate team size; (3) healthy team dynamics – absence of dominant team members; (4) professional facilitation; (5) team tenure; and (6) sufficient time available.

Commitment to the team, resulting in active participation in the decision-making leading to more creative team output, was dependent upon diversity of mindsets within the team: more diversity resulted in less commitment. Team diversity of mindsets has potential advantages. Being able to reap these benefits is depending on whether the disadvantages of team diversity can be mitigated: lower commitment and less supportive team climate due to less 'voice'. Team reflexivity - a deliberate process of discussing team goals, processes, or outcomes - can function as an antidote to tackling these disadvantages. Team reflexivity can help to prevent misunderstandings

in a demanding, knowledge-intensive environment (Schippers et al., 2014). Team learning is enhanced through facilitated knowledge sharing. Teams that are capable of identifying knowledge gaps and crossing knowledge boundaries integrate knowledge involve intense participation and learning of all team members. The more diverse teams are, the greater the dynamics of knowledge assimilation and transfer, to each other within a creative team. Teams increase their capacity to deal with their diversity when team members are able to adjust themselves to organize and synthesize knowledge in the entire team (Yeo, 2020).

Limitations: Like all research, the contribution of this study can be assessed only considering its purpose and methods. There are some limitations to our study. First, we used self-assessed scores of team performance. To increase the robustness of our conclusions, future research would clearly benefit from incorporating multiple and objective measures of team creativity. Second, our data were based on a limited student sample. We suggest to expand the research to business environments, include qualitative research to detail and unravel the social processes within creative teams, and increase the sample of the research. Third, the results were generated in a specific context: a short-term creative problem-solving assignment of ad hoc teams using the LSP method. It would be interesting to retest the research using a creative problem-solving assignment in a longer period, within teams in which members have more (and longer) experience with each other, or using other creative techniques.

Contribution: This paper increases the understanding of preferred team diversity and addresses the dynamics of innovation team processes. Team composition should be adjusted to the phase of the innovation (exploration vs. exploitation). In exploration, more team diversity is needed than in exploitation. To implement innovations successfully, team members must be (1) aware of the preferred styles of behavior of themselves and their team members, (2) adapt and connect with their team members and (3) learn to benefit from differences with the team to improve creative team performance through increased reflexivity.

Practical implication: Innovation leaders and their teams can use our results to deal effectively with team diversity in skills trainings through awareness of relationship dynamics in different phases of the innovation process, to improve a supportive innovation team climate and boost commitment to the innovation teams. We advise to include issues of team composition, preferred styles of behavior and cooperation styles within teams in educational and training programs of members of innovation teams.

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Gamification in Cybersecurity Education; the RAD-SIM Framework for Effective Learning

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Abstract: The effectiveness of gamification in educational technology and digital learning environments has been the subject of research for over a decade. Gamified interventions encourage active learning by promoting role-playing, mentalisation, and experimentation. Learner-centred approaches have been shown to increase learning outcomes compared to traditional methods in some domains. Although the behavioural drivers associated with gamified learning are now well documented, practical advice for game designers who produce workplace training is much less common. This paper proposes the RAD-SIM framework for behaviourally effective cybersecurity games design, whereby psychological and behavioural principles are combined with learning theories to facilitate practical game-based learning. Using the framework will increase the engagement and retention of knowledge of the end-user. Although designed with cybersecurity training in mind, there are implications for educational game design in general. Future avenues for research, including potential case studies in practice, increasing the customisability of gamified interventions, and utilising natural data from organisations are considered.

Keywords: learning, gamification, cybersecurity, games design.

1. Introduction

Over the last three decades, digital technology has grappled to find its place as an educational tool. Although it has clear educational benefits, a trial-and-error approach has led to misguided application. Game-based learning (GBL) has been shown to increase reported enjoyment and engagement with educational content across domains, which is often the first hurdle for successful learning. There has been a particular focus on engaging children and young people by using GBL approaches (e.g., Gros, 2007; Hamari, et al., 2016; Miller, 2015; Ott & Pozzi, 2012), but there is a growing literature which supports their use with older audiences (Charlier, et al., 2012; Wang & Burton, 2010; Whitton, 2011). Furthermore, GBL can increase problem-solving abilities and promote faster knowledge acquisition, compared to traditional teaching methods (Perrotta, et al., 2013). A recent literature review of 24 empirical research papers found that GBL may also increase both the quality and quantity of data available to researchers in this area, as well as facilitate the learning process in content-heavy subjects such as science and mathematics (Kalogiannakis, et al., 2021). The review found that GBL in science education can have a positive impact on academic performance more broadly, suggesting a permeating effect of gamification across different contexts.

However, the evidence that GBL is an effective method of teaching is inconsistent and often unreliable, in part because of a reliance on small sample sizes and a focus on undergraduate and WEIRD populations (Alwi, et al., 2017; Kebritchi, et al., 2010; Kosa, et al., 2016). Evaluating GBL in organisational settings can help fill the gaps resulting from this imbalance. Creating a broader understanding of the behavioural mechanisms associated with GBL by examining its effect on adults of all ages will provide a much richer understanding of the behavioural drivers of learning in general. Since learning is a ubiquitous feature of all domains, creating an evidence base which documents the pitfalls and potential of GBL interventions is valuable to practitioners of all professions.

GBL approaches are increasingly popular in the field of cybersecurity, perhaps because of a growing consensus that cybersecurity is not just a technical specialism. As such, organisations need a training medium that is not only effective but also well-received. This has resulted in a wealth of literature on GBL cybersecurity interventions, with a target population of varying abilities, contexts, learning preferences, motivations, and social environments. This plethora of scientific and industry material presents an opportunity to investigate the behavioural drivers and contextual factors associated with GBL across several fields, such as criminal justice, healthcare, education, and psychology. Building upon a literature review focused primarily on gamification in the field of cybersecurity, the RAD-SIM framework is proposed as a practical guide for training designers to follow when creating gamified interventions. The RAD-SIM framework combines practical elements of

gamification (behavioural response, perceived attack, and game design) with the behavioural principles of sociality, incentivisation, and mentalisation to promote more effective gamification in cybersecurity training.

2. Method

2.1 Research Questions

The overarching question of "How can gamification best support the training of users against socially engineered cyber-attacks?" was separated into three targeted research questions for literature review:

1. What gamified training works best for who, how, and why, to protect against different types of socially engineered cyber-attacks?
2. What empirical evidence supports these claims?
3. What types of gamification have been developed for other sectors that may be relevant to this area?

The aim of the literature review was to construct a narrative using these questions as a guide. This resulted in a general description of GBL literature across the cybersecurity domain, with reference to other relevant fields. This formed the foundation for the RAD-SIM framework.

2.2 Generation of Coding Criteria for Literature Review

An interdisciplinary subject matter expert (ISME) workshop was conducted by a panel including an Applied Behavioural Scientist; a Senior Lecturer in Childhood Studies, an Educational Psychologist; a Social Psychologist; and a Cyber Risk Specialist. The scoping parameters and coding criteria for the literature review were identified and used to create a table of PICO search terms. This translated into search strings (available upon request) used to search PsychINFO, Web of Science, Scopus, and ACM Digital Library.

A total of 250 papers were coded for this review. Identifying information was recorded alongside details specifying focus (e.g., cybersecurity-related, or not). The 'key gist of results' was recorded qualitatively, and relevance to theory was noted. Coders used a strategy as defined in the ISME workshop, identifying themes related to user vulnerability (e.g., phishing), types of training (e.g., cybersecurity specific), different user needs (e.g., learner differences), domains of interest (e.g., online/offline training), organisational/user processes (e.g., influence) and assessing impact (e.g., evaluation method).

2.3 Content Analysis and Narrative Synthesis

Content analysis was used to identify prominent concepts/themes relevant to the coding protocol. Researchers used keywords, determined in the search protocol, to identify the frequency of themes throughout the literature by counting the number of times each keyword was used. These keywords were then clustered into broader themes using a qualitative method and discussion within the team. Clustered themes were organised into a coherent structure using narrative synthesis. By exploring relationships between themes across the literature, a logical and comprehensive description of ideas were articulated. This method allowed the research team to draw meaning from a wide range of sources and create rational answers to the three research questions.

2.4 Creating the RAD-SIM Framework

Using the findings of the literature review and a second ISME workshop, the RAD-SIM framework (Figure 1) was designed using three learning theory frameworks. Behavioural and social learning theories were considered due to their relevance to social norms and pressures in the learning process. This includes both a behaviourist view of learning, in which learners are driven to pursue rewards and avoid punishment by classical and operant conditioning (Skinner, 1957), and the perspective of Social Learning Theory (SLT), which posits that individuals learn vicariously by watching others (Bandura, 1977). The classical conditioning and trial-and-error theories of learning of Pavlov (1928) and Thorndike (1911) were taken into consideration. Cognitive Learning Theory (CLT) (Yilmaz, 2011), which proposes that learners explore their environment by building on their existing cognitive structures or schemas, was explored in relation to potential behaviours within gamified learning. CLT promotes student-led/-centred learning, rather than teacher-centred. Theories of social constructivism (SC) were evaluated in relation to game-based training. SC asserts that learning occurs when we create meaning from experience. The mind acts as a filter of information, attending to what is interesting/relevant and ignoring less salient stimuli. The SC perspective is that knowledge is socially constructed; the 'Zone of Proximal Development' (Vygotsky, 1986), is a learning environment in which individuals can build on their own knowledge using the knowledge of their teachers and peers in an environment that fosters active learning. These theories supported the foundation of the RAD-SIM framework.

3. Proposing the RAD-SIM Framework

This section proposes and explains the RAD-SIM framework, which is intended for use as a prompt when designing GBL activities. Figure 1 visualises the five key categories for consideration when designing GBL or training programs, including the subcategories which contribute to each. The framework aims to provide GBL designers with a step-by-step guide for creating GBL based on behavioural principles. The subsections below explain the rationale for each component with support from the literature, as well as some of the key points to consider when designing a game.

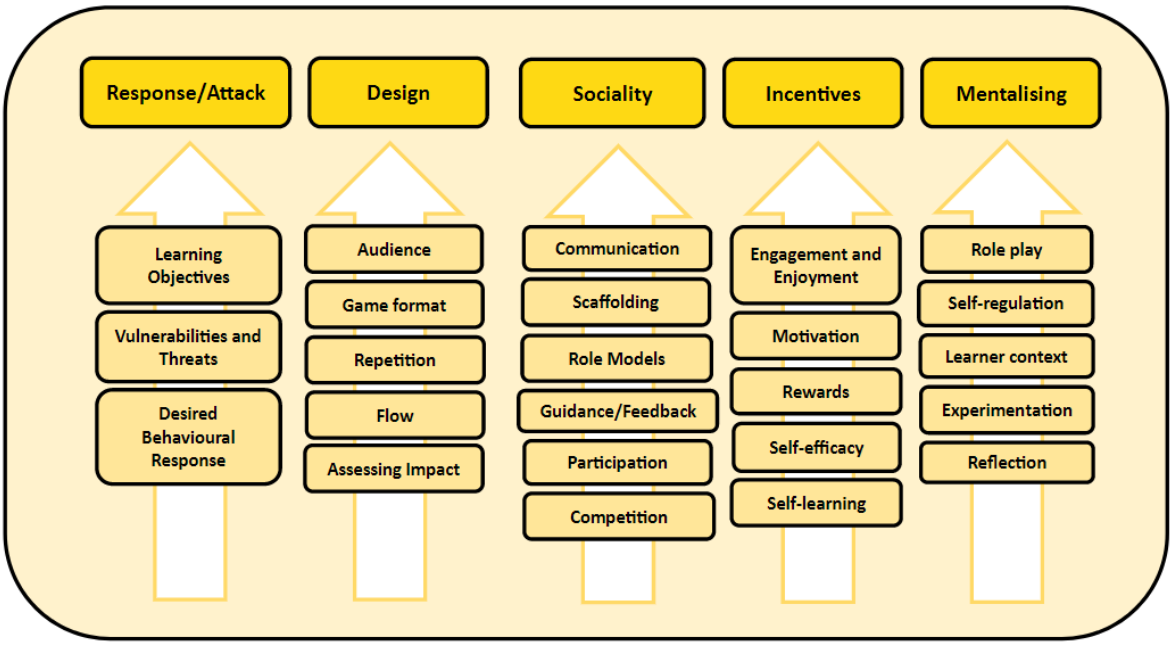


Figure 1: The RAD-SIM framework and associated sub-components

3.1 Response/Attack

The literature indicated that evaluating the success of GBL relies on the initial outlining of specific learning objectives (Silic & Lowry, 2020). Although these objectives can be differentiated for audiences/abilities, they provide an important benchmark against which to measure impact. Outlining learning objectives at the earliest stage of game design ensures that activities are geared toward helping learners achieve these goals from the outset, providing focus/direction for the designer.

This component includes consideration of desired user responses when different vulnerabilities are targeted. As the literature review focused primarily on the domain of cybersecurity, there is a focus on identifying the key vulnerabilities/threats that a user needs to be protected against in a digital context. Desired behavioural responses can then be established (e.g., recognising/eporting phishing emails); this forms the basis for determining learning outcomes/bjectives. This process can be extended to other domains.

Evidence from the literature suggests that training alone does not necessarily lead to consistent behaviour change (Salas & Cannon-Bowers, 2001). However, repeatedly targeting the same learning objectives may help to reinforce knowledge, leading to increased learning over time (Cujzek & Vranic, 2016). This variation in the effectiveness of GBL emphasizes the importance of tracking performance over extended periods. In an academic setting, this information may contribute to the current understanding of the longevity of learning and the effect of training on memory. In an applied setting, it may inform how often training must take place to maintain desired behaviour.

3.2 Design

The design component of the framework focuses on the intended audience, game format, elements of repetition, flow, and methods of assessing impact. Evidence shows that the audience should be at the centre of an intervention design to promote maximum engagement (Beguin, et al., 2019; Deeb & Hickey, 2019; Jøsang, et

al., 2020; Luh, et al., 2020; Oroszi, 2019). Not only must the game be appropriate for the learner's ability (Bakker, et al., 2015; Mayer, et al., 2013), experience (Pina & Bordonaba-Juste, 2018), and context (Staller & Koerner, 2021), but the identification of these characteristics is essential for accurately positioning the difficulty of levels and the rate of progression through the game. Games that were too difficult for a player lead to disengagement (Pusey, et al., 2014), as did over-familiarity with content (Pan, et al., 2017; Zargham, et al., 2019).

As maintaining an element of challenge is key to sustaining player engagement with the intervention throughout their experience, some key questions at this stage of design are "why is the user engaging with the intervention?", "in what context are they learning?", and "how much support might the user need to participate in the game?". In response to these questions, a designer should choose a game format, for example, a simulation, card game, escape room, or capture-the-flag game. It is important to examine the practicalities of formats in relation to the end user's needs; financial cost, timescale, and remote/in-person delivery are examples of potential considerations. Two studies suggested that increased awareness of wider context might directly improve recall due to an increase in attention, leading to higher knowledge consolidation and improved memory (Williams, et al., 2014). Incorporating elements of repetition should be considered by the designer, as repetition can help improve recall (Papies, 2017). However, a designer should remember that repeated information needs to be presented in a variety of ways; direct repetition, though necessary to secure longer-lasting learning, can become monotonous.

Perhaps most importantly, a designer needs to plan the flow of a user's experience through the game. Pace will be a subjective indicator to the participant, but the designer should incorporate features such as visible/trackable goals to provide a tangible measure of progress/development. This allows users to receive feedback on their actions, providing a greater understanding of their current ability and areas for progress. Flow is an important factor in maintaining concentration and engagement, both of which are broadly demonstrated to be key to achieving positive learning outcomes across the literature.

A way to assess the impact of an intervention, based on learning objectives, should be embedded within the game. This should incorporate both performance- and practice-based metrics to capture a comprehensive understanding of learner development. Where possible, pre/post-intervention testing can help to establish the efficacy of an intervention; several studies across the literature engaged in this type of testing (Deeb & Hickey, 2019; Konig & Wolf, 2018; Mostafa & Faragallah, 2019; Raman, et al., 2014; Ross & Bennett, 2020; Tobarra, et al., 2020) but many lacked evaluation.

3.3 Sociality

Sociality requires engagement with others in group-oriented games. Engaging with others not only creates an opportunity for competition and collaboration, but also promotes vicarious learning using role-models (Bandura, 1977), and further building on this foundation by scaffolding knowledge (Vygotsky, 1986). In addition, communication and interpersonal social skills have been shown to be transferable to other contexts (Rooney & Whitton, 2016) and are therefore likely to be useful across learning environments and beyond. The most common features of sociality in the literature are communication (Yang, et al., 2012), scaffolding (Barzilai & Blau, 2014), role models (Scholl, 2019), guidance and feedback (Kumaraguru, et al., 2010), participation (Koch, et al., 2012), and competition (Alqahtani & Kavakli-Thorne, 2020; Amo, et al., 2020; Anvik, et al., 2019; Gjertson, et al., 2017; Scholefield & Shepherd, 2019). Communication provides learners with an additional opportunity to gain knowledge and should be encouraged throughout the game by encouraging collaboration or competition with others. Some participants may prefer working independently and should be given the opportunity to learn from observation rather than participation. Encouraging communication is also key to promoting scaffolding, whereby players can discuss difficulties and strategies. This allows them to help each other to improve their individual knowledge bases. By promoting active, student-centred learning, participants construct their own meaning and acquire knowledge as a group. Role-modelling should be incorporated into GBL design where possible, either by using a stronger, more experienced, or more successful 'real' player or by creating a relatable fictional character. Players learn from the examples set by role models, and role models have a great deal of normative and informational social influence.

Guidance and feedback are therefore vital components of the sociality aspect of RAD-SIM. Feedback can be provided by in-game characters, teachers/tutors, other participants, or the player themselves. Furthermore, receiving feedback in the form of points can help to reinforce positive/desired behaviours and guide a player through the training, creating a greater sense of flow. Feedback is useful for building user confidence and self-

efficacy as it acts as a signpost to their progress within the training. Feedback and guidance help to promote greater participation by acting as an incentive. Across the literature, participation was shown to be maximised by making the game as engaging/enjoyable as possible. Competition can be used to further increase enjoyment and has been shown to make learning more effective (Sepehr & Head, 2018). However, not all individuals will be motivated by a competitive element, so competition should not usually be made a mandatory component of GBL.

3.4 Incentives

Incentives motivate players to learn and engage with the game (Alqahtani & Kavakli-Thorne, 2020). The identified subcomponents are engagement and enjoyment, motivation, rewards, self-efficacy, and self-learning. As previously stated, enjoyment and engagement are vital to creating a successful game. Players who report high levels of enjoyment participate in gamified training for longer than with traditional teaching materials, increasing their opportunity to learn (Mostafa & Faragallah, 2019). Games can be made enjoyable using compelling narratives, pleasing aesthetics, in-game rewards, and accessible game mechanics. Participation, engagement, and enjoyment influence motivation, which can either be intrinsic (e.g., they find the game exciting) or extrinsic (e.g., they want to succeed against others). Rewards fuel extrinsic motivation and utilise the natural human drive to engage in reward-seeking behaviour. Rewards can take many forms, including positive feedback, points, prizes, or increased reputation. Rewards should be used to encourage behaviours, knowledge-seeking, or longer participation.

Promoting self-efficacy and confidence drives intrinsic motivation. Learners should feel that they can progress through a game and have the capability to acquire knowledge. Players should also build confidence in their ability to recognise when to behave in a certain way or apply their recently developed knowledge base. Self-efficacy can be encouraged by appropriately targeting content to the learner's ability; starting at too difficult a level will not promote feelings of confidence or capability (Pusey, et al., 2014). Furthermore, allowing players to navigate the content at their own pace ensures that individuals are sufficiently challenged, but not pushed too far out of their comfort zone; games could be programmed to detect these changes. Designers should promote active self-learning, whereby players choose to independently seek out additional resources and experiences to improve their knowledge. There is evidence to suggest that GBL makes participants more likely to engage in further learning outside of an intervention (Huang & Hew, 2018), therefore education/training providers should make sure that there are resources available for individuals to continue their development outside of the game. It is this self-learning that is most meaningful to the learner, resulting in the longest-lasting effects.

3.5 Mentalising

Mentalising allows a learner to consider how they or others would think/act in a situation, helping them to develop a better understanding of themselves and other people. This encourages participants to reflect on their knowledge and behaviour, understanding how their mental states have an impact on outcomes (Rahim & Minors, 2003). The mentalising aspect of the RAD-SIM framework includes role-play, self-regulation, learner-context, experimentation, and reflection. Role-playing is an essential part of a learning experience and allows a learner to consider their thoughts and actions in different contexts and circumstances, thus gaining a better understanding of their own mind (Guenier, et al., 2022), whilst also providing an opportunity for practice. Role-playing prepares learners for a range of real-life scenarios, helping them to recognise real-world threats/opportunities (Rahim & Minors, 2003). Role-playing also encourages adversarial thinking, prompting them to adopt an oppositional mindset, considering how an adversary might think or act (Gondree, et al., 2013). Not only does this help the player to identify their own potential vulnerabilities, but it also promotes more advanced critical thinking and consideration (Dark, 2014). This process may help users to develop their higher-order thinking.

Learner context is an important consideration in GBL design and content should reflect the topics that players might encounter in real life. However, there is also a need to consider audiences' attitudes toward subjects, as gamification can provide a 'mask' which makes learning information more enjoyable by presenting it through an alternative topic (Staller & Koerner, 2021). Increased enjoyment leads to experimentation within and outside of the learning environment (Huang & Hew, 2018), leading players to use trial-and-error learning to construct their own meaning. Players should be encouraged to consider material critically and creatively to adapt to different situations; experimentation creates an opportunity to develop these skills. Mentalising can further improve a learner's ability to self-regulate their behaviour, responding rationally to different situations (Rahim & Minors,

2003). GBL gives learners the opportunity to practice responding to emotive events, giving them a certain level of inoculation against similar scenarios in the real world (Calvo-Morata, et al., 2020).

Game designers should encourage players to reflect on their experiences of the game; reflection is an important skill which allows a player to objectively consider their past thoughts and behaviour and help them to encode learning from the short-term to the long-term memory (Mitchell & Hill, 2019). This further consolidates learning and should be encouraged by presenting opportunities for discussion with other players or by creating structured, scheduled breaks for self-reflection.

4. Conclusions and Future Study

The most substantiated finding from across the literature is that GBL is useful for increasing engagement with educational content, and it is this increased attention and participation which leads to improved recall, greater awareness, and enhanced cognitive control. Although this finding was not supported in every case, there is enough variance in contextual factors to suggest that individual differences and the level of context-dependent specificity are at least partially responsible for this differentiation. This potentially indicates a lack of flexibility, adaptability, and customisability in current game designs. These features were identified in the literature review, and subsequently the RAD-SIM framework, as being necessary components of successful GBL. Whereas practitioners should seek to incorporate these elements into new or existing training structures, researchers might consider exploring the precise value of customisability in relation to other elements of the RAD-SIM framework.

Considering this finding, GBL may be particularly effective for participants who must complete mandatory learning/training in educational and organisational settings. Participants who elect to engage with GBL may already have a strong sense of motivation to engage with the materials. On the other hand, mandatory training sessions are often considered repetitive and disengaging, resulting in poor learning outcomes and ineffective learning culture (Sloman & Borattino, 2007). Although the current focus is on applying GBL to cybersecurity training, in the future it is hoped that there will be a reconfiguration of all mandatory work-based training, with the goal of increasing the retention of knowledge and promoting positive behaviour change. The latter four categories of the RAD-SIM framework (Design; Sociality; Incentives; and Mentalising) would certainly cross-apply to other professional environments, for example, diversity and inclusion training or organisational cultural development. Research must shift its focus from small scale studies to meta-analyses with a statistical focus; this review took a qualitative approach; however, it is decidedly clear that a quantitative strategy would provide more insight. A significant limitation of this review is that both the content analysis and narrative synthesis introduce a subjective component (and potentially bias) into the analysis of information from the literature. However, it is hoped that the proposal of the RAD-SIM framework and relevant themes has given enough insight to prompt further investigation in this field. Similarly, this review was somewhat constrained by time and resource budgets, as it was not conducted by an academic institution. It is hoped that there will be scope for a more quantitative approach for this work in the future. In contrast, however, taking a qualitative approach allowed the researchers to cover a broad range of papers and topics within this domain, ultimately contributing to the wider discussion of GBL training in cybersecurity and beyond.

An important benefit of using GBL approaches to education and training is the ability to collect information on the progress of individuals and groups over time and across topics. This allows training providers and educators to track the development of users and adjust to increase engagement of learners. It also provides researchers with a potential source of data. Much of the current literature focuses on lab-based interventions and self-report surveys, however, there is great potential to utilise this natural data to investigate real-world facilitators/barriers to learning. Strengthening the relationships between education, industry, and academia is a vital process which has benefits for all parties; education/industry sectors can develop more efficient, functional tools, and academia is able to make reliable predictions based on accurate real-world data. The field of GBL is an emerging catalyst for nurturing this symbiotic relationship.

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Game-based Learning. A tool that Enhances the Collaborative Work: A Case study of Undergraduate Students

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Abstract: The way a professor teaches in the classroom mostly at the undergraduate level is constantly changing, and this is reflected in how pedagogical resources are transformed. What was previously unthinkable to use in the classroom is now standard, including an impactful tool, the video games. This digital tool, over the years, has positioned itself as an element that goes beyond entertainment, and have proven that thanks to the interaction that it provides the alumni has gain more capacities and tools beyond the academic goal. The objective of this work was to delve into the relevance of *Game-Based Learning* (GBL) and how it affects students to develop and acquire teamwork competency and strengthen peer collaboration. This paper aims to show the results obtained from the research and analysis of 99 undergraduate students enrolled in creative studies; specially, the majors that are included are: communication, digital art, marketing, musical production, architecture, and industrial design, all these students are part of private college in Puebla, México. The quantitative methodology used a six-item, Likert-scale instrument. This questionnaire was applied to undergraduate students in academic programs related to the creation of multimedia and transmedia content and other creative areas. The results indicated that the students appreciated the educational methodology of using video games as a didactic tool and this creates that the students get more involved not only with the classes, but with their own learning. It must be cleared that this kind of methodology must be applied during the sessions, and, of course, it helps if cooperation exists among the class members inside and outside the classroom. Also, this tool supports teachers in improving class dynamics and the way of teaching changes allowing them to assume a new role as a guide to knowledge and encourager of more student interactions. Thus, recreational activities utilizing video games in various activities potentiates educational innovation. These tools positively impact students' education as their acceptance and willingness to use them improve their learning process.

Keywords: game-based learning, educational innovation, professional education, higher education, teamwork, collaboration

1. Introduction

Students are not just entertained by videogames, in fact, they learn, acquire skills, and develop specific competencies that help them to thrive in various live fields. On the other hand, the teaching profession faces various changes brought about by the impact of technological devices on the dynamics of teaching and learning. Traditional teaching strategies have become obsolete; therefore, teachers must look for new ways of teaching and connecting students to learning. Therefore, Information and Communication Technologies (ICT) and social transformations make it essential to apply new strategies, including a Game Based Learning (GBL) process, where game mechanisms help students acquire and strengthen their knowledge (Gil and Prieto, 2018).

The information previously submitted helps as a basis to understand that videogames can make college learning more dynamic, active, and less inhibited; with this, it can be achieved that the students pay more attention to the content transmitted in the classes.

Considering the above, this research aims to establish the relevance of GBL as a didactic technique, especially considering that teaching strategies based on games combine play, collaborative work, creativity, and imagination to strengthen the learning and teaching process. It is decided to carry out a field study with undergraduate students and verify whether the premise is true. Specifically, this study explains how video games are part of Game-Based learning and encourage collaboration; in addition, videogames develop activities that strengthen students' understanding and encourage decision-making.

2. Theory approach

The pedagogical use of ICT is fundamental to making the educational processes effective in all disciplines. It is necessary to leverage the new generations' natural relationship with digital tools; they become bored without them. The students are more distracted when they do not use technology in class (Rodríguez, Ramírez and Fernández, 2017); therefore, the concept of play as a free, interesting activity of daily life acquires much relevance because, thanks to video games, the feeling of fun and the users' engagement increases (Braghirolli, (Ribeiro, Weise and Pizzolato 2016)

The education sector is dynamic; it offers new technologies and game dynamics that enable students to participate actively in the learning process through activities and problem-solving. Digital tools make learning more visual, reinforcing creative capacity and improving students' ability to manage information, cooperate, and think critically. These systems help reduce the fear of making mistakes, favoring trial-and-error processes that allow mistakes to be rectified (Martínez, 2017).

As an educational innovation, the game is a didactic resource for developing various topics in the curricular content, promoting cognitive progression, and strengthening the relationship between students and teachers (Hierro and Pastor, 2020). This didactic technique supports student interactions to generate patterns, deduce information, and generate strategies based on new experiences; therefore, games become an educational tool promoting theoretical and practical learning linked to life experiences (Ahamer, 2012). Through different techniques, knowledge is acquired due to video games' interactive characteristics, allowing to establish and test new strategies. In addition, they offer the opportunity to learn while performing a mission (Waiyakoon, Khlaisang and Koraneekij, 2015).

Game-based learning fosters motivation promotes competency training and influences behavior; this didactic resource provides numerous benefits for both students and teachers, including high levels of motivation, activity, and promotion of creativity (Parra, Segura and Romero, 2020). In addition, using games in academic activities increases students' concentration, effort, and motivation (Sánchez, 2015).

The definitions, positive aspects, and characteristics of the GBL are diverse; however, there are certain aspects in common: the use of strategies, models, dynamics, and mechanics that aim to transmit a message or contents through an experience that motivates, engages, and entertains (Martínez, Pérez and Martínez, 2016).

Despite the benefits of GBL, the methodology is criticized because of a myth that learning and playing should not be linked. However, one argument in favor of the combination relates to the demands of the new generations, who continuously interact with digital technologies. GBL creates and modifies attitudes and aptitudes in students; due to their cognitive evolution, students can establish relationships and retain much more information (Landers, Armstrong and Collmus, 2017).

As for learning, several definitions include one by Guerrero (2014): it is the process of acquiring knowledge, skills, attitudes, or values through study, experience, or teaching. Gallardo and Camacho (2018) point to learning as a development caused by day-to-day activities. Based on the above and for this research, the learning is viewed as a complex system that acts on the human being and allows him to generate new knowledge. The process allows people to adapt to new situations through developing new skills or improving those already acquired (Londoño and Rojas, 2020).

Video games in non-playful contexts are reflected in the field of education; the balanced use of these provides a series of physiological contributions, for example, the release of epinephrine and dopamine in the brain, in addition to evoking good feelings that potentiate receptivity to learning (Barata, Gama, Jorge and Gonçalves, 2013).

Therefore, the motivating components of the game must be leveraged and transferred to formal contexts to involve users in complex processes and guide them towards the acquisition of learning. Thus, students increase their commitment and participation in educational activities when facing challenges and missions in games (Quintana, 2014). Different studies point to the need to look for methodologies that use gamification as a tool to improve the teaching and learning process. For example, Marín and García (2005) underscore the ability of video games to foster various skills, such as curiosity to learn, curricular transversal competencies, and reinforcement of self-esteem. Specifically, they mention action or sports video games to promote psychomotor development, ocular and manual dexterity, and spatial orientation. Adventure and role-playing games help develop knowledge. Simulations help control tension and develop imagination, and strategy games improve the ability to manage resources.

Thus, as an essential element of GBL, video games help education through immersive activities that cause feelings of absolute dedication, inferring that "gamifying" is a methodology that goes beyond applying a game (Perrotta, 2013).

For its part, playful pedagogy is a response to new educational possibilities. It is necessary to rethink the importance of play and the playful environment as a pedagogical meeting place; it must relate and be immersed in a contextualized didactic project with significance and transformation (Carolei, 2016).

Faced with these different teaching and learning techniques, students and teachers acquire new roles. The teacher must be involved in the educational processes, prepared to present change processes, and open to adapting to daily shifts. Also, the teacher must become an active change agent who can create, propose, evaluate, and communicate the proposals derived from the learners' daily experiences and their contextual environments. In addition, teachers should consider game-based learning as a stimulating tool that boosts students' enthusiasm (Aznar, Raso, Hinojo & Romero, 2016).

As for the students, this educational model proposes that they develop the ability to think and reason by reflecting on their decisions. The game helps them learn to make quick, coherent, and concrete responses to decisions. Thus, the students internalize what they have learned and receive training for competencies they will need in their professional futures (Parra, Segura & Romero, 2020).

It should not be forgotten that teachers teach classes to "digital natives," who characteristically use different digital devices daily in their leisure time for personal development. Therefore, games can motivate and attract this generation and including game elements motivates them, providing an opportunity to reduce the lack of commitment to learning (Simões, Díaz & Fernández, 2012).

Finally, due to the new teaching methodologies, students should see that their opinions have value, they can follow their passions and interests, create new things using all the digital tools that surround them, work through group projects, make decisions, share leadership, cooperate and compete; that is, they should feel that the education they receive is relevant and has value (Prensky, 2005)

For this analysis, the video game is defined as software that aims not only to entertain but also to generate learning in the participants, helping them develop logical, numerical, and technical skills through experience. In addition, they are considered tools to be used for educational purposes. In this sense, Sampedro, Muñoz & Vega (2017) comment that video games can be used as educational tools and are elements applicable to daily routines.

Over 30 years of evolution, video games have incorporated the characteristics and capabilities of new technologies that combine several audiovisual languages, interactivity, information processing, and connectivity (Boscan, Pirela and Velásquez, 2017). It should be noted that video games allow experimenting with identities, exploring new experiences, and even testing the limits of those who play. In addition, they improve attention, concentration, and strategic planning. Other analyses indicate that they promote tolerance towards different ideologies and thoughts and help develop multidisciplinary knowledge, which gives rise to logical and critical thinking (Perrotta, Featherstone, Aston & Houghton, 2013).

Educational institutes' use of video games leads developers to create stories that support experiential learning (Ortíz, Jordán & Agredal, 2018). Therefore, growing interest in using these tools in learning processes and education has arisen because video games facilitate achieving various objectives of the participants. These include diagnosing and improving organizational processes, teaching, or reinforcing concepts of a specific theme, and determining situations of group behavior, all through activities that make learning a friendly process (Londoño, 2014).

When analyzing the structure of a video game, there are similar characteristics to key aspects in the design of educational activities. Three fundamental features evidence such an analogy:

- Goal orientation: the games seek to reach a goal in each time; there are some limitations, but these must be overcome, and, in the end, there will be an apprenticeship.
- Recognition: As the processes continues, there are awards and recognitions that encourage the person to continue.
- Progress: depending on the progress, the student's progress is presented, the more semesters he/she attends, the more knowledge the students have; the same thing happens with games, the more levels a person advance, the more tools this person have so he/she can complete the game.

These three characteristics of video games apply in education and the design of training activities, which supports the feasibility of integrating video games into educational activities.

3. Methodology

This study used a quantitative, cross-sectional methodology from December 2020 to January 2021. There was no modification of variables. The study subjects were the students that are part of a private university in Puebla, Mexico. The population sample comprised the alumni concentrated in undergraduate creative studies programs, including architecture, digital arts, communications, design, and music production. It should be noted that the selected population derived from the direct contact with them, this means that the person who writes this paper belongs and teaches in this area, also, it has direct contact with the teachers that teaches this kind of courses. The other reasons for having selected this sample are:

- This type of curriculum aligns with the project creativity that students usually develop.
- Teachers often use innovative didactic techniques to fortify the teaching and learning process.
- The author of this article studied this area and personally knows these degree programs profoundly.

The population sample to which the measurement instrument was applied consisted of 99 students, which are the totals that are part of the "Creative Study" area. Note that the questionnaire developed was based on previous theoretical and literary research. Before applying the surveys, a pilot study was conducted to thoroughly analyze the questions to be applied. They were shared with another population sample, and the necessary corrections were made. Afterwards, the questionnaire had the following items, which were measured using a five-point Likert scale with the options strongly agree, agree, neutral, disagree, and strongly disagree

1. Game-based learning is a necessary tool for the teaching process.
2. Game-based learning develops teamwork skills.
3. Game-based learning drives educational innovation.
4. Game-based learning makes collaborative work more robust.
5. The teachers with whom I take class use the game-based technique.
6. Comments about game-based learning.

The questions described above were to know the students' perception before GBL and its typical use in the courses, its impact on students, and how this technique can be applied to reinforce learning and encourage collaborative work. The procedure by which this questionnaire was shared was through the *Google Forms* tool. It was used to list the student emails to whom the instrument was sent. They were asked to kindly respond to the questionnaire with the same platform.

4. Results

Once the measuring instruments were applied, we analyzed the questionnaire responses. The following graphs illustrate the results:

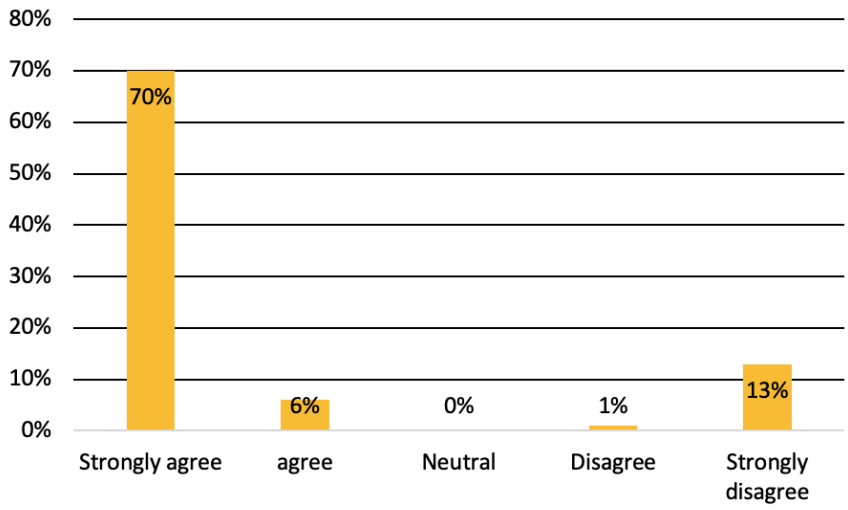


Figure 1: Question 1: Game-based learning is a necessary tool for the teaching process

Figure 1 indicates that most students considered game-based learning necessary for their learning process. Seventy per cent confirmed that this tool strengthens teaching and promotes dynamics for greater interest in the sessions. However, it should be noted that 13% mentioned that game-based learning is not essential to developing their knowledge. Finally, from this question, it´s fair to say that video games are an ideal tool for both students and teachers to have a better teaching and learning process.

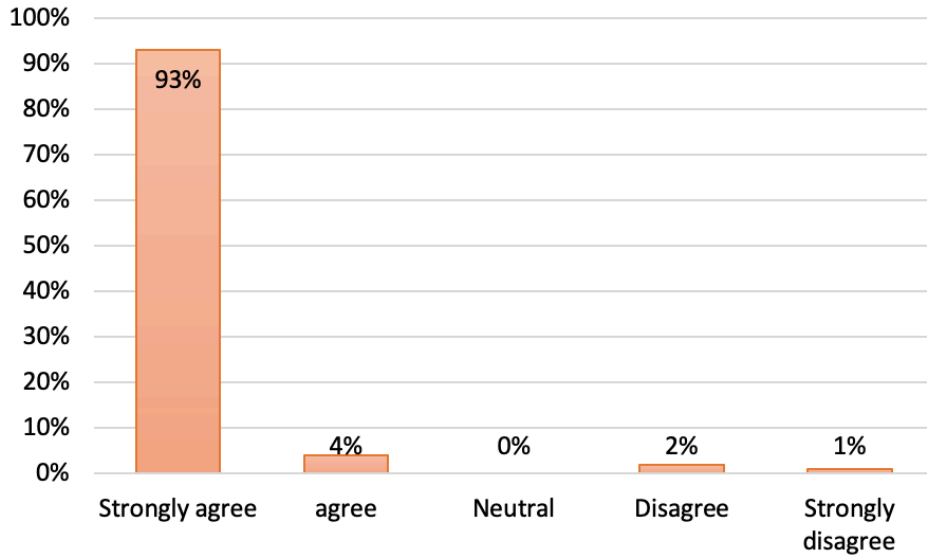


Figure 2: Question 2: Game-based learning develops teamwork skills

This graph shows that 93% of respondents strongly agree that video games increase their teamwork skills. Although they collaborate through a console to overcome the game's challenges, the students can transfer these skills to academic questions, i.e., collaboration becomes more common, and school projects can be completed timelier and with better results. These types of results are more visible when using games with stories that require the immersion of a team to perform a mission. It must be added that, as they advance, the students receive medals, achievements, and prizes that serve as an incentive. It should be noted that only 2% of respondents said they disagreed, and 1% strongly disagreed with the statement that Game-Based learning promotes teamwork.

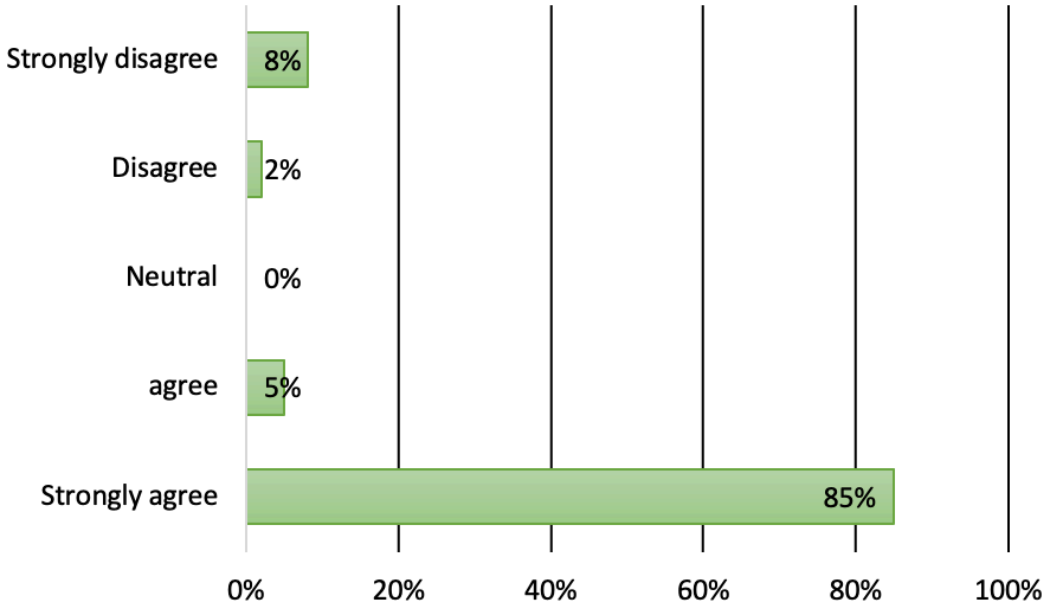


Figure 3: Question 3: Game-Based learning drives educational innovation.

Game-Based learning is a fundamental part of educational innovation; therefore, students must answer this item. This question seeks to clarify whether this technique improves and potentiates the dynamics of teaching

and learning processes. Only 10% answered negatively (adding the strongly disagree and disagree responses) that this is not the case and that there are other ways to innovate education. However, most of those who answered this survey (85%) affirmed that the methodology based on games is undoubtedly a tool that encourages educational innovation and should be leveraged by teachers in the course designs.

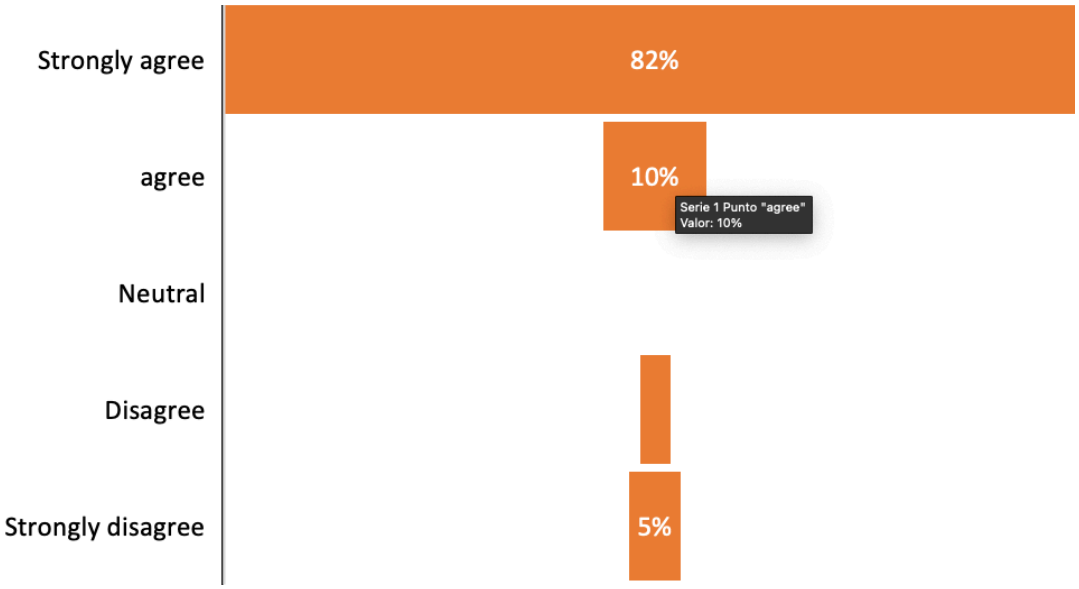


Figure 4: Question 4: Game-Based learning makes collaborative work more robust

One of the advantages of video games is that they encourage the ability to work as a team due to their dynamics, the platform, the narrative, the interactions among characters, and even achieving common goals or objectives leads to greater participation together.

Therefore, students were asked about the potential of Game-Based learning relative to teamwork and collaborative learning. The results showed that more than 80% of students affirm that this type of teaching strengthens collaborative work. Only 5% answered that they strongly disagreed, that means that various games and playful activities of these tools help students think in a group way and reduce individualism.

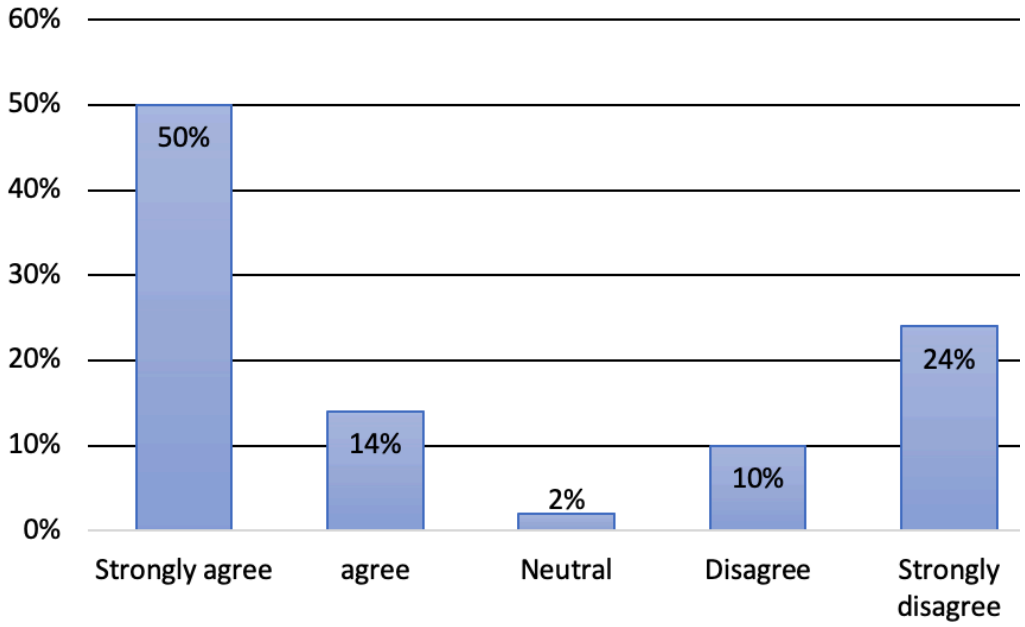


Figure 5: Question 5: The teachers with whom I take class use the Game-Based technique

This last graph shows students' perspectives on their teachers' interaction with Game-Based learning. The respondents' answers are interesting. On the one hand, 50% say they strongly agree that teachers use some

methodological tools based on games to strengthen teaching and make it more active; however, 24% strongly disagreed that the methodology was used in the subjects they had studied. The above shows a contradiction. On the one hand, students know that learning based on games is vital for skills development, fundamental to educational innovation, and improves the teaching and learning process; however, they note that many professors do not use this technique.

After analyzing the instrument results and the students' experiences and testimonies, it can be seen that the GBL technique satisfies some needs, such as the feeling of achievement and desire for reward, prestige, and recognition. It promotes collaboration and teamwork or well-intentioned competitiveness.

It also indicates the need to bring students closer to immediate interactivity in their learning. Using these tools strengthens creativity, personal relationships, and dynamism to understand the topics covered in the class sessions. Above all, these findings challenge teachers to develop other types of class sessions that are not passive, where both students and professors are involved in the educational process.

It should be noted that, although the study focuses on numerical analysis of specific items, it also collected comments and observations vented by the respondents. These reveal that the students have a general knowledge of this dynamic and understand the need to use this technique in sessions or classes. They commented that the ideal is that the teachers involve them in the dynamics of teaching and learning and provide better feedback.

Finally, the students assured that video games could be an excellent resource for class teaching and exemplify theoretical issues covered in the sessions. They commented that the more complex and complete the game's narrative in question, the more robust is the learning, but the important thing is that the faculty is involved in this type of tool to achieve a better result.

5. Conclusions

The results analysis allowed detecting the positive effects of Game-Based learning that promoted teamwork and collaboration among the students. In addition, students tended to be more active during the learning process. Consequently, they are protagonists and builders of their learning. Similarly, creativity is put to the test by both teachers and students. The results of our study of the GBL approach point to the tool as a didactic methodology that can be applied to different undergraduate programs to help both students and teachers develop new roles.

On the other hand, the application of video games in education is a field of knowledge still being analyzed, and there are some challenges. These include the application of practical evaluation tools, analysis of behavioral data resulting from applying the games, finding a balance between learning and fun, and how to address the actual, contextual needs of the participants academically; therefore, the work must continue.

The study results verified that the objectives established were achieved by the methodology employed. Above all, incorporating Game-Based learning can be a relevant dynamic perfectly executed inside and outside the classroom. The ideal is that, through this tool, students can address complex challenges that improve their learning.

Moreover, teachers must have the ability to employ these tools to strengthen educational processes and add energetic dynamics to their class sessions. It should be remembered that the students accept and enjoy this technique and that, according to the study, they are willing to have more significant interactions in the classroom.

Finally, to strengthen this type of analysis, it is pertinent to conduct comparative studies of different academic course designs and to know the students' perceptions of these dynamics inside and outside the classroom. It would also be interesting to study the teachers who apply and who do not apply the GBL in their different subjects. With this, you can measure and compare the levels of learning that the students have in the topics presented in the class sessions throughout the academic period.

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Player perceptions of informal learning in non-educational games

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Abstract: The potential of non-educational games in learning is well-established, but there have been relatively few empirical studies attempting to explore the kinds of informal learning take place in non-educational games outside of formal education. Simultaneously, student motivation is known to have a connection to learning outcomes, but there is a lack of research on the relationship between gaming motivations and informal learning in games. This paper aims to fill the gap in research by, firstly, forming an empirically-based understanding of what players perceive they are learning from playing non-educational games, and secondly, exploring the potential connections of self-articulated learning outcomes with motivations to play games and preferences for gameplay activities. The research data was collected through an online survey panel. The respondents were asked to describe in open-text answers what they had learned by playing games, and their motives and gameplay activity preferences were measured using two psychometric instruments, Motives of the Autonomous Player, MAP (Vahlo and Tuuri, submitted) and the gameplay activity inventory GAIN (Vahlo et al, 2018). The open-text responses analysed using data-driven content analysis, which resulted in 11 main categories of learning outcomes. Cluster analysis of the main categories revealed three clusters indicating informal game-based learner types: (1) Learning perseverance, learning mainly related to coping skills and self-enhancement, (2) Learning practices and communalities, focusing on practical and interpersonal skills, and (3) Learning to perform, emphasising cognitive and sensori-motor competencies. Comparisons of the learning outcome clusters with motives and gameplay preferences revealed the learner types had distinct profiles which denote differences between learner types in the overall motivation to play games, in certain motivational factors, and in preferences of gameplay activities. Based on this analysis we suggest the existence of two distinct continuums, transfer of learning, and the situational dependence to gameplay activities, where these learner types are located.

Keywords: informal learning, learner types, non-educational games, learning outcomes, gameplay motives, gameplay preferences

1. Introduction

Unlike the purposeful activities that individuals and communities do, play does not seem to have an obvious goal. Play appears to epitomise humans' desire to act on a purely voluntary basis – often just for fun. However, this is not to say that play would not have any benefits. From the developmental and evolutionary perspectives, human play and games have functioned as crucial forms of learning (e.g., Bruner et al, 1976). For children, playing might be just a fun activity, but at the same time, children develop physical or social skills that are relevant in their future (Piaget, 1962[1951]). Furthermore, it is intriguing to consider play as an activity that satisfies basic human needs of self-determination, especially in terms of fulfilling the desire to experience autonomy (Deci and Ryan, 2012). Thus, it is worthy of further exploration to consider the 'autonomous player'.

Non-educational games is a term used in the context of game-based learning to describe games designed for entertainment as opposed to educational games which are designed for learning. Our focus is on informal, spontaneous learning occurring by voluntarily playing non-educational games. In this millennium, informal learning has also become an area of interest for educational policy makers in the European Union as a method of lifelong learning, which has been considered as a solution for the needs of the European labour market (Tuschling & Engemann, 2006; Panitsides & Anastasiadou, 2015). Informal learning, where learning takes place even when it is not the main objective of an activity, is an integral part of modern video game design, as games are designed to teach their players how to play them (cf. Gee, 2003; Poretski and Tang, 2022). However, we are interested in the diversity of informal learning taking place when playing non-educational games. Instead of asking how games can be used in teaching, we study the perceived learning outcomes of playing games. In this study, this is essentially done in an open-ended manner, giving people the opportunity to describe what they have learned without presenting them with any presuppositions. The main goal of this study is to form an empirically based understanding of what players perceive they are learning from non-educational games, and how they conceptualise learning in self-report studies.

Due to the close relationship of play and learning, it is tempting to consider the possibility of similarities between the motives of an autonomous player and the learning outcomes yielded by gameplay. Student motivation is known to have a connection to learning outcomes (e.g. Janosz, 2012), but there is a lack of research on the

relationship between gaming motivations and informal learning in games. The secondary goal of this study is to investigate, do motives and learning outcomes together form observable patterns. This question is addressed using a psychometric, validated instrument, MAP, that measures motive dimensions of autonomous gaming (Vahlo and Tuuri, submitted). Furthermore, using the gameplay activity inventory GAIN (Vahlo et al, 2018), we study player preferences of particular types of gameplay activities and investigate their possible associations with perceived learning outcomes.

First, we address existing research in learning from non-educational games. Then we introduce the data and qualitative analysis methods. The results are presented in three sections: qualitative analysis and formulating learning outcome categories, cluster analysis of the data, and statistical analysis of the connections of learning outcome clusters with MAP and GAIN respectively. This is followed by discussion and conclusions.

2. Informal learning from games

Non-educational games, despite their name, have been frequently used for educational purposes (Squire, 2003; Egenfeldt-Nielsen, 2006; Wastiau et al, 2009). Research on the use of commercial off-the-shelf games in education has identified their potential in learning skills such as dealing with depression (Olson, 2016), teamwork and other social skills (Sherry, 2016; Silva et al, 2021), attention abilities (Franceschini et al, 2013), and enhancing cognitive performance (Dale and Green, 2016). Furthermore, non-educational games have been used in teaching a variety of subjects such as languages Chen and Yang, 2012; Reinders, 2012), history (Squire 2005), and science (de Aldama and Pozo, 2020). Majority of this previous research on learning from games has studied learning outcomes using skill-testing or other forms of formal learning assessment.

There have been surprisingly few empirical studies tackling the question of what kinds of informal learning take place while playing and how players themselves perceive their learning (Gee, 2003; Iacovides et al, 2014; Matijević and Topolovčan, 2019). This research aims to take a more comprehensive approach by mapping out the variety of informal learning taking place in non-educational games.

3. Data and qualitative methods

The data (n=1202) for this study was collected via Prolific, a crowdsourcing platform that holds an online panel in multiple countries. Using online panels in survey research has been found particularly appropriate for explorative research such as the one reported here (Lehdonvirta et al, 2020). The survey was targeted at adult (ages 18-70) UK or USA residents who reported playing videogames at least occasionally. We asked the respondents to describe in their own words what they had learned by playing games and 95.2% (1145) answered this voluntary question.

We used qualitative data-driven content analysis to form categories of self-identified learning outcomes from these responses. After excluding the responses not answering the question, there were 1046 responses (86.9% of the whole data) which discussed learning outcomes. Each response was read and placed into one or more categories, which were created as the analysis advanced. This meant that the data had to be reread several times in order to include the new categories. However, while aiming for an open-ended approach to analysis, the categorization was undoubtedly influenced by the researcher's previous conceptual models related to learning. In the next stage of the analysis, based on joint review by all authors similar categories were further grouped under different main categories turning the initial categories into subcategories.

4. Results

4.1 Learning outcomes

Our analysis identified 117 different subcategories of learning. These included categories with only one or two responses but in the most common categories there were more than 100 responses ('problem solving', 'language skills', 'hand-eye coordination'). The subcategories were grouped into 11 main categories, which represent a wide variety of learning in terms of their contents. A single response was typically placed into one (32.1% of responses) or two (30.6%) categories of learning outcomes, but the maximum number of categories for a response was 13. Next, we will explicate the main categories (Table 1).

Table 1: Learning outcome main categories

Main category	Responses (f)	Responses (%)
Learning to play	111	9.2%
Learning about games	37	3.1%
Learning about self	101	8.4%
Thinking skills	651	54.2%
Interpersonal skills	294	24.5%
Embodied behaviors	301	25.0%
Subject matter	276	23.0%
Practical skills	281	23.4%
Coping skills	185	15.4%
Self-enhancement	170	14.1%
Learning to learn	18	1.5%

Learning to play. This main category included respondents reporting that playing games had taught them to play those particular games. Some of the responses in this category were laced with scepticism towards the possibility of learning anything from games, as in the following quotation.

> *I do not think I have learned anything from video games, apart from how to play the game in question. I think they are too limited and abstracted to be of any use in real life.*

In addition, *learning to play* included learning to play games in general, learning to play games of a particular genre, such as FPS (first person shooter), or evolving in particular game techniques like aiming or puzzle-solving. In the following example, learning to play is described as becoming familiar with conventions of game design.

> *I learned that if you are meeting enemies then you are going the right way.*

Learning about games. Self-articulated learning outcomes also reached to game cultures more broadly. This meant learning about the fictional game worlds but particularly about game communities, their composition ("many of the gamers are older than I expected"), and communication. This included insights into game culture phenomena, such as 'toxic' behaviours or online identities, the latter reflected in the following.

> *I've learned that people like to portray things within the games that they cannot in real life. They can be almost anything they want to be or do anything they want to do in a virtual world.*

Learning about self. Related to *learning about games* is also the subcategory of learning about one's own gaming preferences such as liking certain genres or preferring single-player or multiplayer games. However, this subcategory shares more similarities with those related to self-discovery. The following response portrays the intertwinement of an increased understanding of personal game preferences (playing alone) and learning about self more broadly (wanting to achieve things by themselves).

> *I like playing skill games and it made me realize I like to play alone and achieve things on my own.*

Thinking skills. This was the most common main category emerging from the analysis. Problem-solving was the most common subcategory of thinking skills and one of two most common learning outcomes in the data. Other prominent learning outcomes from this main category were planning, strategizing, management skills, critical thinking, and creativity.

I have learned how to keep better track of time and how to strategize when I do things throughout my life.

Interpersonal skills. Collaborating and cooperating with others was mentioned often in the responses, along with communication skills. Learning interpersonal skills were sometimes situated in particular social contexts. Respondents described learning online communication, or learning "to interact with people in a competitive setting". Another common interpersonal skill was an increased understanding of how to form relationships.

I have learned how to build team friendships and motivating fellow players.

Embodied behaviours. Hand-eye coordination, muscle memory, reaction time, and dexterity were among the most common embodied behaviours in the data. Mentions of these are straightforward, like this one: "I have learned better hand-eye coordination and finger dexterity." Other subcategories are memory, spatial awareness and pattern recognition. Interestingly, this main category also includes mentions of purposefully using games to improve certain skills.

Playing video games helped my eye/hand coordination after having surgery on my hand.

Subject matter. Several respondents recounted learning about particular subject areas, such as history, geography, other cultures, mathematics, and science, while some mentioned even more particular subjects like cars, weapons or sports.

I have learned more about the rules of sports when playing games like Fifa.

Respondents often specified they now had improved their knowledge on a certain topic, while some described it as learning "facts"or "trivia".

Practical skills. Learning new languages or developing existing language skills was one of the two most common learning outcomes. There were also mentions of several technical skills, from learning to efficiently use a computer keyboard to advanced skills such as coding. The variety of skills extended from storytelling to business skills. Some mentioned applying these practical skills to real-life situations, as in the following.

I now have a much firmer grasp of how maps translate into real world environments.

Coping skills. The most common coping skill emerging from the data was perseverance, often described vividly as by one respondent narrating, they had learned to "try again and again until I find the right combinations to win". Several respondents mentioned learning skills pertaining to self-regulation, such as controlling their emotions or behaviour, or managing stress.

I've learned that playing video games is a great way to relieve stress and escape from your problems for a bit if you need to do so.

Self-enhancement. Several learning outcomes in the data were related to attitudes or personality traits, like determination, and flexibility. One respondent described learning "[h]ow to be more patient, how to not rush at things and take your time to make the right moves". Indeed, patience was the most common learning outcome in this main category. Another interesting subcategory was 'confidence' as exemplified in responses such as "[playing] helps to reassure that I'm still skilled at something".

Learning to learn. A small but noteworthy category among the learning outcomes was learning to learn. Some responses described particular learning techniques such as 'note-taking' or 'researching strategies'.

4.2 A Cluster Analysis on Informal Game-Based Learners

We proceeded to explore what kinds of groups could be identified from the survey respondents based on their self-articulated responses. Based on the results of the qualitative content analysis, we constructed eleven binary dummy variables for each survey participant. Value 0 or 1 was then assigned for participants for each variable based on whether they had described the learning main category or not in their open-ended responses, not depending on whether they had mentioned one or more of its subcategories.

An exploratory cluster analysis with Stata 16.2 software was conducted to investigate how main categories of learning outcomes were associated with each other on the level of the survey participants in order to identify learner types in the context of informal learning from games. We began the clustering procedure by examining the data to identify the optimal number of clusters that ought to be extracted. This was done by searching for kinks in the scree plots that were generated from the within sum of squared (WSS) or its logarithm [log(WSS)] for all possible cluster solutions between 2 and 20 clusters (Makles, 2012; Figure 1). As both WSS and log (WSS) clearly suggested a solution of three learner types, we decided to construct three learner clusters.

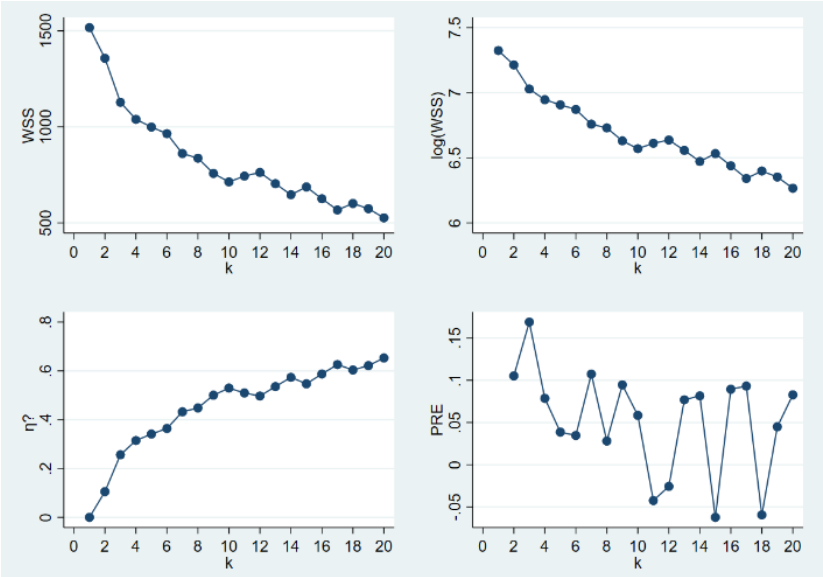


Figure 1: Scree plots for identifying the correct number of clusters, based on which a 3-cluster solution was selected

We then conducted an unsupervised K-Means clustering for a three-cluster solution using the Jaccard index. K-Means is a partition cluster analysis method which groups observations into a number of clusters that do not overlap. The Jaccard procedure calculates binary similarity coefficients based on proportion of matches when the value of each included variable is 1. In other words, the three clusters (Table 2) were formed based on co-occurrences of the main categories of learning outcomes in the data. The whole survey sample of 1,202 respondents were included in the cluster analysis.

Table 2: The three clusters of informal game-based learners, their cluster sizes and proportions in the learning outcome main categories

	Cluster 1 Learning perseverance	Cluster 2 Learning practices and communalities	Cluster 3 Learning to perform
N	323	278	601
Learning to play	2.2%	5.4%	13.5%
Learning about games	1.2%	3.2%	3.8%
Learning about self	1.9%	6.1%	11.3%
Thinking skills	0.0%	5.0%	72.7%
Interpersonal skills	0.0%	55.4%	13.6%
Embodied behaviours	0.3%	15.8%	31.8%
Subject matter	15.5%	21.2%	14.1%
Practical skills	0.0%	59.7%	11.6%
Coping skills	24.1%	8.3%	9.3%
Self-enhancement	17.6%	11.2%	11.3%
Learning to learn	1.9%	1.1%	1.5%

Apart from the main category of *Subject matter*, which is relatively equally distributed across the clusters, the three resulting clusters seem to represent clearly distinctive types of learning outcomes (Table 2). (1) The first cluster appears to denote learning outcomes relating to learners themselves and especially to the development of patience and perseverance in overcoming the challenges of life (*coping skills*, *self-enhancement*). (2) For the second cluster, the learning outcome main categories that differentiate it from the other two emphasise practical everyday skills that are often embedded in social communities (*practical skills*, *interpersonal skills*). (3) The third cluster appears to represent performance-oriented cognitive and sensori-motor competence (*thinking skills*, *embodied behaviours*) that most closely seem related to the gameplay-situated, strategical, logical and embodied skills needed for performing well in a game.

4.3 Player Motivations and Preferences

Next, we investigated how the identified learner types were associated with prevalent motives to play videogames, that is, if and how motives related to e.g. competition, autonomy, or social interaction were linked with one or more of the three learner clusters. This was done by applying the Motives of the Autonomous Player (MAP) inventory, which is a recent nine-factor model of gameplay motives that is currently being validated. We furthermore applied a psychometric instrument to study if types of gameplay appreciation was related to the clusters. This was studied by making use of the five-factor gameplay activity inventory (GAIN).

Cronbach's alphas (95% confidence intervals for the alphas) for each of the MAP and GAIN factors were calculated for the sample, and these are reported below in the brackets:

MAP is a 34-item inventory (Vahlo and Tuuri, submitted) that assesses nine prevalent and general motives to play videogames: *Immersive agency* (α=0.83, 95% CI: 0.81-0.84), *Competitive mastery* (α=0.84, 95% CI: 0.82 to 0.85), *Affective engagement* (α=0.86, 95% CI: 0.84 to 0.87), *Nostalgia* (α=0.88, 95% CI: 0.87 to 0.89), *Utility* (α=0.86, 95% CI: 0.85 to 0.87), *Social* (α=0.90, 95% CI: 0.89 to 0.91), *Addiction* (α=0.87, 95% CI: 0.86 to 0.89), *Escapism* (α=0.84, 95% CI: 0.82 to 0.85), and *Boredom* (α=0.76, 95% CI: 0.74 to 0.78).

GAIN is a 15-item instrument (Vahlo et al, 2018) for studying players' preferences in distinctive types of gameplay activities. In short, the instrument assesses what kind of player engagement is attractive for players, when engagement is understood as participating in gameplay through *Aggressive* α=0.83 (CI 0.82 to 0.85), *Explorative* α=0.75 (CI 0.72 to 0.77), Coordinative α=0.65 (CI 0.61 to 0.68), *Caretaking* α=0.73 (CI 0.70 to 0.76), or *Managing* α=0.65 (CI 0.62 to 0.68) modes of interaction.

As a next step in analysis, sum variables and standard deviations were generated and calculated for the nine-factor MAP and five-factor GAIN constructs, as well as all of their factors for the three learner clusters (Table 3). We calculated one-way analyses of variance (ANOVAs) between the three clusters for motive and gameplay activity factors to identify if there were statistically significant differences between the group means.

Table 3: Motive and gameplay activity type factor-level mean sumsas well as average motive and gameplay activity sums across all factors for the three learner clusters. One-way analyses of variance (ANOVAs) between the cluster means: *p < 0.05, ** p < 0.01, and *** p<0.001

	Cluster 1 Learning perseverance (N=323)		**Cluster 2 Learning practices and communalities (N=278)**		**Cluster 3 Learning to perform (N=601)**		**Model**
	Mean	SD	Mean	SD	Mean	SD	
Immersive Agency***	3.77	1.27	4.37	1.24	4.11	1.27	MAP
Competitive Mastery***	3.54	1.31	4.01	1.38	3.89	1.30	MAP
Affective Engagement***	5.58	1.03	5.97	0.88	5.84	0.86	MAP
Nostalgia***	3.89	1.50	4.42	1.46	4.31	1.47	MAP
Utility***	3.62	1.51	4.18	1.50	4.11	1.49	MAP
Social***	3.70	1.58	4.64	1.57	4.12	1.62	MAP
Addiction	2.43	1.23	2.65	1.31	2.50	1.37	MAP
Escapism**	5.11	1.24	5.46	1.27	5.27	1.07	MAP

	Cluster 1 Learning perseverance (N=323)		**Cluster 2 Learning practices and communalities (N=278)**		**Cluster 3 Learning to perform (N=601)**		**Model**
Boredom	4.81	1.34	4.80	1.39	4.83	1.27	MAP
Aggression***	4.19	1.58	4.69	1.49	4.48	1.61	GAIN
Caretaking	4.29	1.26	4.49	1.36	4.38	1.31	GAIN
Coordinate	4.33	1.30	4.33	1.35	4.40	1.25	GAIN
Management	4.45	1.17	4.66	1.17	4.60	1.17	GAIN
Exploration**	5.38	1.16	5.71	1.10	5.66	1.08	GAIN
Average motive sum (AM)***	4.05	0.92	4.50	0.90	4.33	0.85	
Average GAIN sum (AG)***	4.53	0.88	4.78	0.91	4.70	0.81	

A one-way analysis of variance comparison of average motive sum variables (the AM variable in Table 3) between the three clusters revealed that participants of Cluster 2 were more motivated to play than those of Cluster 3 (p=0.0071, Cohen's d=0.20, 95% CI: 0.05-0.34) and Cluster 1 (p=0.0000, Cohen's d=0.50, 95% CI: 0.33-0.66). With the exceptions of *Addiction* and *Boredom*, there were statistically significant differences in all motive factors between the clusters. For Cluster 1 and Cluster 2 the effect sizes between the means were most notable in *Social* (Cohen's d=0.60, 95% CI: 0.43-0.76), *Immersive Agency* (Cohen's d=0.48, 95% CI: 0.32-0.64), *Utility* (Cohen's d=0.37, 95% CI: 0.21-0.54), and *Nostalgia* (Cohen's d=0.36, 95% CI: 0.20-0.52) motives in which Cluster 2 had cleary higher mean values than Cluster 1. Cluster 2 and Cluster 3 were relatively similar to each other regarding their motive means. Yet the Welch t-test (one-sided) found statistically significant differences between these two clusters in *Social* (p=0.0000, Cohen's d=0.33, 95% CI: 0.18-0.47), *Immersive Agency* (p = 0.0047, Cohen's d=0.21, 95% CI: 0.06-0.35), *Affective Engagement* (p=0.033, Cohen's d=0.15, 95% CI: 0.01-0.30), and *Escapism* (p=0.027, Cohen's d=0.16, 95% CI: 0.02-0.30) motives. In all of these cases, the mean values of Cluster 2 were higher than those of Cluster 3.

As for the five types of gameplay activity preferences, only *Aggression* and *Exploration* sums differed between the clusters. Cluster 1 had lower *Aggression* preference than both Cluster 2 (Cohen's d=0.32, 95% CI: 0.16-0.49) and Cluster 3 (Cohen's d=0.18, 95% CI: 0.05-0.32). The same was true for the *Exploration* sum between Cluster 1 and Cluster 2 (Cohen's d=0.29, 95% CI: 0.13-0.45) and Cluster 1 and Cluster 3 (Cohen's d=0.25, 95% CI: 0.12-0.39).

5. Discussion and conclusions

The outcomes of informal learning in this study are based on our analysis of players' own perceptions of learning from games. We identified 11 main categories of learning outcomes. To identify potential learner types we conducted a cluster analysis. Together with comparisons between these three learner types (*Learning perseverance*, *Learning practices and communalities*, and *Learning to perform*) it revealed that players do differ from each other in what they perceive and articulate they have learned by playing games of their choice. The first notable result of the clustering process was that it clearly suggested a three-cluster solution. Each of the three clusters denoted different profiles of learning, respectively emphasising the specific areas of self-development, improving communal practices, and improving performative abilities in terms of both cognitive and behavioural skills. It is tempting to reflect on this result from the perspective of self-determination theory (Ryan and Deci, 2000), especially in terms of the three basic needs that constitute positive growth and motivation of individuals. Thus, it seems possible to make obvious linkages between the needs of Autonomy, Relatedness, and Competence, and the respective clusters of *Learning perseverance* (supporting autonomic self-development), *Learning practices and communalities* (supporting social relatedness), and *Learning to perform* (supporting the development of competence). This kind of interpretation would, however, require future studies focusing particularly on the prospect of this promising observation.

Secondly, the three learner types did have distinctive profiles, not only regarding the experienced learning outcomes but also player motives and preferred gameplay activity types. The main result of these comparisons was that the *Learning perseverance* type of player-learners were notably less motivated to play games than the other two learner types, yet they enjoyed gameplay activities of coordination, caretaking, and management similarly to the *Learning practices and communalities*, and the *Learning to perform* player-learners. The *Learning*

practices and communalities player-learners differed from the *Learning to perform* player-learners in a much more subtle way, mostly regarding the *Social* motive and the *Immersive Agency* motive.

These results indicate that playing because of social and immersive experiences is associated with a high motivation to play games and, importantly, also with learning outcomes related to interpersonal and practical skills (e.g., language skills, teamwork). Furthermore, we found that another, highly motivated player-learner type that was not as motivated by social and immersive experiences reported learning outcomes that were closely associated with performance, competence, and honing skills by overcoming game challenges. The third, less motivated learner type perhaps considers games more as a method for self-development, self-enhancement, and coping, and thus has a more instrumental relationship with game experiences than the other two learner types.

On the level of gameplay activity types, it seems that game activities that enable aggressive (e.g. shooting, killing) and explorative gameplay (e.g., character development, narrative progression) are attractive to players who (report to) have learned *practical skills*, *interpersonal skills*, *thinking skills*, and *embodied behaviours* by playing non-educational games. For the player-learners of the *Learning perseverance* type, the aggressive and explorative gameplay is not similarly attractive, which means that this learner type has more balanced gameplay preferences. Perhaps this is another indicator of them being more focused on self-development, the game and the social interactions it may enable. Related to this, it should be asked whether perceived learning and psychological need satisfaction, as argued in the SDT framework, are somehow related to each other. Our results seem to indicate that game-based learning might be closely associated with user gratification and satisfaction that players derive from games.

Given that all three learner types outlined stem from voluntary play of non-educational games, it is interesting to note how each cluster varies in terms of how dependent the learning outcomes are on gameplay (Figure 2). Most notably, the *Learning to perform* cluster seems to incorporate the closest situational dependence to the engagement with gameplay activities and "doing well" in answering the game's challenges. This interpretation is underlined by a fact that this cluster included the largest amount of learning outcomes that were explicitly about *learning to play*. On the other end of the continuum, *Learning perseverance* cluster seems to manifest skills that are most transferable to different contexts of everyday life, while also bearing the least amount of skills with direct dependance to actual gameplay (e.g. strategizing, sensorimotor skills). The second cluster, *Learning practices and communalities*, is positioned between the other two, as it seems to both denote practical and interpersonal skills that are highly transferable while also associating with more gameplay-dependent similar skills as in the case of the third cluster.

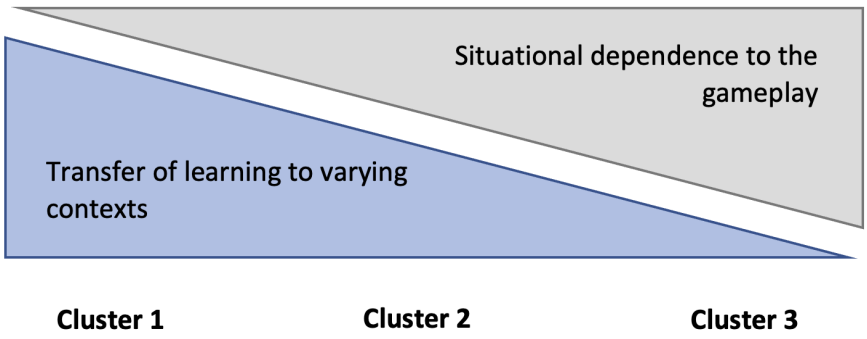


Figure 2: The two-way continuums of the transfer of learning and the dependence of learning in relation to the three clusters of learning outcomes

This study demonstrated that it is possible to identify distinct informal game-based learner types based on players' self-articulated learning outcomes. Furthermore, our analysis substantiated that these learner types are distinctive from each other also in relation to gameplay motives as well as preferences for particular gameplay activities, thus, strengthening their profiles. Further research should delve into the possible connections between informal game-based learner types and the needs outlined in self-determination theory, also because

motives to play digital games have already been extensively studied in the SDT framework (Ryan et al 2006; Przybylski et al 2010).

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How to Welcome First-year Students: Best Practice of a Gamified Orientation Day

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Abstract: Various difficulties characterise students' adaptation to university. It is crucial to engage first-year students from the first moment of university entrance, to support their transition from secondary to higher education, and to facilitate their learning experiences and learning outcomes. This study starts from the dual premise that orientation activities offer first-year students important transitional support to cope with the stressful challenges while enabling a sense of community, and that, as students sometimes consider orientation activities as tedious, gamification might make participation more enjoyable, while stimulating students' motivation and information retention. Based on educational literature on gamification of learning settings, this study presents the design, implementation, and evaluation of a gamified orientation day, organised for first-year students. The design of the gamified orientation day is based on the eight gamification features of Apostol, Zaharescu and Alexe (2013): players, story, goals, rules, problem solving, feedback, safe environment, and sense of mastery. The objectives of the orientation day and its practical implementation are explained on the theoretical basis of these eight features. Qualitative survey data (*N*=1326) were collected to evaluate the strengths of the orientation day and the areas for further improvement. The data show that students perceive the gamified orientation day as a pleasant learning experience. Students appreciate collaborating with peer students and their active participation in knowledge acquisition. This study provides evidence-based best practices for the gamification of orientation days, and aims to inspire other universities in adapting their strategy on facilitating the transition and orientation of first-year students.

Keywords: gamification; higher education; first-year experience; first-year students; orientation day; university transition

1. Introduction

Engaging first-year students from the moment they enter university is crucial to facilitate their transitional period from secondary to higher education, as well as their learning experiences and learning outcomes Conley *et al.*, 2014). During university entrance, students often face various transitional challenges (Vinson *et al.*, 2010). Orientation days offer valuable transitional support, as they "normalize the stress and distress that come with this exciting yet disruptive transition, … and ensure that students know concrete steps for utilizing support services" (Conley *et al.*, 2014, p. 206). Additionally, participation in orientation activities is beneficial to first-year students' sense of community and social integration, and counteracts loneliness (Myrtveit *et al.*, 2017). Research on the effectiveness of orientation day offers various best practices: e.g., activities in small groups, supported by student-centered university staff, should encourage active information acquisition (Vinson *et al.*, 2010). As students often perceive orientation activities as tedious, Fitz-Walter et al. (2012) argued that gamification makes these learning experiences more enjoyable and engaging. Recent studies have explored the benefits of gamified orientation days: students explore the campus and connect with peers, which strengthens their sense of belonging, while being motivated to actively learn crucial know-how on the university culture (Fitz-Walter, Tjondronegoro and Wyeth, 2012; Bürgisser *et al.*, 2018; Salisbury, Rossiter and Ung, 2018). Additionally, Brull et al. (2017) demonstrated that gamification outperforms other orientation didactics regarding students' information retention.

Literature from various disciplines investigated gamification: "game design elements in non-game contexts" (Deterding *et al.*, 2011) arousing gameful experiences to foster behavioural outcomes (Hamari, Koivisto and Sarsa, 2014). Within the educational discipline, especially higher education research and practice, gamification has shown great potential in engaging students and enhancing their learning processes (Caponetto, Earp and Ott, 2014; Manzano-León *et al.*, 2021). Gamified learning benefits university students' cognitive and behavioural outcomes (Hamari, Koivisto and Sarsa, 2014; Sailer *et al.*, 2017), and enhances engagement, motivation, and academic achievement (Apostol, Zaharescu and Alexe, 2013; Faiella and Ricciardi, 2015; Brull *et al.*, 2017; Manzano-León *et al.*, 2021). Positive consequences of gamification are explained based on several educational premises: e.g. the goal-setting theory, flow theory, and self-determination theory (SDT) (Bai, Hew and Huang, 2020). However, some scholars also demonstrated gamification to negatively affect motivation (Faiella and Ricciardi, 2015). On the question of how many game elements are needed to qualify as gamification of learning, Kapp (2012) responds that "multiple elements are required to make a game an effective learning experience"

(p. 50), and argues that some elements are more crucial in supporting learner engagement and motivation that others. Whilst points, badges, and leaderboards – i.e., the PBL triad – are frequently implemented elements (Bai, Hew and Huang, 2020; Manzano-León *et al.*, 2021), they lead to decreased intrinsic motivation and increased extrinsic motivation, due to external reward stimulation, and social comparison and competition (Hamari, Koivisto and Sarsa, 2014; Hanus and Fox, 2015). Implementing PBL is insufficient and solely entails superficial engagement, Kapp (2012) argues; instead, 'deeper game elements' are the story, safe environment, challenge, and sense of mastery. In this regard, Faiella and Ricciardi (2015) highlight clear objectives, challenging tasks and authentic narratives, that stimulate a sense of belonging. Additionally, timely, regular, and appropriate feedback is curial in gamified learning (Domínguez *et al.*, 2013). Finally, gamification should provide a sense of novelty and enjoyment (Perrotta *et al.*, 2013; Faiella and Ricciardi, 2015). The framework of Apostol, Zaharescu and Alexe (2013) summarises these design elements, crucial to create meaningful gamified learning environments. The framework distinguishes eight features of gamification: players, story, goals and clear outcome, rules, problem solving, feedback and rewards, safe environment, and sense of mastery.

This study focuses on a gamified learning environment organised for first-year students entering university: an orientation day particularly designed with the objective of enhancing the social integration, information retention, and engagement of first-year students, while stimulating them to explore the campus in a pleasant manner. The design of this gamified orientation day is based on the eight features of Apostol, Zaharescu and Alexe (2013). The aim of this study is twofold. First, it offers an overview of the theoretical design and the practical implementation of the gamification of an orientation day for first-year university students (Section 2). Second, qualitative data serve to explore how students perceive this gamified orientation day (Sections 3 and 4). Finally, the conceptual design and the evidence-based results are jointly discussed (Section 5).

2. Features of a gamified orientation day

What follows, elaborates on the design and implementation of this study's gamified orientation day, based on the eight features of Apostol, Zaharescu and Alexe (2013). Each subsection focuses on one feature with first, a theoretical overview of the relevant literature on gamification and orientation activities, followed by a discussion of how these insights were incorporated in the design and implementation of the orientation day. Each feature contributes to the dual objective of the gamified orientation day. The first objective relates to the students playing the game, whilst the second objective comprises the orientation processes.

2.1 Players

Crucial to gamified learning is the social mechanism: enabling players to share experiences and build connections over a mutual goal (Perrotta *et al.*, 2013). The ways in which players may interact with each other are highly diverse. Some gamification settings primarily induce cooperation by facilitating players to collaborate in teams, whereas other settings mainly foster competition between players (Kapp, 2012). Gamification characterised by collaboration is considered beneficial to students' sense of relatedness and feelings of enjoyment (Sailer *et al.*, 2017; Bai, Hew and Huang, 2020). Contrastingly, gamification settings that enable competition, might enhance social comparison and discourage students (Domínguez *et al.*, 2013; Hamari, Koivisto and Sarsa, 2014). Hanus and Fox (2015) explain how destructive competition (i.e., as one player/team wins, the other players/teams lose) could damage intrinsic motivation, whereas constructive competition prioritises pleasant experiences and positive interpersonal growth.

Based on these theories, this study's gamified orientation day divided students into small groups of six, with whom they collaborate during the orientation day. Students are assigned a group number at the start, without self-selection. However, what students are unaware of, is that teams are pre-assigned based on tutorial groups which are part of their first-year curriculum. Consequently, during the gamified orientation day, students will get to know five peers with whom they will be in tutorial sessions. In line with scholarly insights, teams are not in direct competition; they proceed at their own pace, with equal opportunities to submit their final answer at the end. Winning teams are determined by the correct answer and by a tiebreaker question.

2.2 Story

"Storytelling is an essential part of the gamification of learning … [a] story provides relevance and meaning to the experience" (Kapp, 2012, p. 41). A story or narrative behind the game, sometimes fantasy-based, is crucial to engage and motivate students (Perrotta *et al.*, 2013; Hanus and Fox, 2015; Manzano-León *et al.*, 2021).

This study's gamified orientation day involves a central narrative: solving the mystery of the famous economist. Following the suggestion of Costa, Viana and Raleiras (2021), a video was developed to effectively involve students in the story. At the start of the day, students watch the video in which a famous economist challenges them to discover their identity. After the video, each team receives a first challenge (i.e., a puzzle). When completed, they receive a folder, containing a booklet with ten possible economists (e.g., Milton Friedman, Elinor Ostrom), and a description of their characteristics (e.g., year of birth, nationality, most important theories). Throughout the game, students can earn clues to discover the right economist. The economists included in the game are chosen deliberately, as their theories are part of the first-year curriculum. To maximize students' engagement and immersive experience with the story (Manzano-León *et al.*, 2021), all game materials (e.g., video, folder, decorations, signposts, posters) were designed in the same theme.

2.3 Goals and clear outcome

Clear goals are essential to effective gamified learning, providing players with a mission or "a sense of purpose" (McGonigal, 2012; Apostol, Zaharescu and Alexe, 2013; Hamari, Koivisto and Sarsa, 2014). Clear goals and outcomes, together with structured rules (cf. below), define gamification, and distinguish gamefulness from more improvisational playfulness (Deterding *et al.*, 2011). According to Kapp (2012), goals should be clear, specific, and immediate, implying that one should see the direct consequences of certain efforts. Moreover, goals should be challenging, though not too difficult (Kapp, 2012; Perrotta *et al.*, 2013).

In this study's gamified orientation day, a video clearly states the goal from the very beginning. Students are informed on how to achieve this: by completing challenges throughout the game. Nevertheless, besides this game-related goal, the orientation day is organised to prepare students for university: it informs students (e.g., course schedule), stimulates them to complete administrative tasks (e.g., curriculum registration, ordering course books), and encourages to explore the faculty buildings and meet peers. Beyond the game-related goal, these practical and social outcomes comprise the orientation day's essential orientation goal.

2.4 Rules

Rules form one of the basic mechanisms of gamified learning settings, distinguishing the systematical and analytical nature of gamefulness from solely exploratory playfulness (Deterding *et al.*, 2011; McGonigal, 2012). According to Perrotta et al. (2013), "rules can be more or less complex depending on the choices they elicit and the related consequences … simple and binary (if/then); or multifaceted and accommodating a broad range of decision making processes" (p. 9).

Students participating in this study's gamified orientation day are informed of the game rules through a folder with all necessary information: a hand-out with guidelines, a booklet with ten economists, the reply form to submit their definite answer, a map of the faculty, and a route description (i.e., sequence of the stations). Team-specific routes are composed so that not all teams take the same route, to avoid 'bottleneck stations'.

2.5 Problem solving

Gamified learning settings confront the players with problems and tasks, typically challenging enough to motivate them though not too demanding to get discouraged, and which engage players to think creatively and logically to reach the goal of the game (Apostol, Zaharescu and Alexe, 2013). Challenges form an essential design principle of educational gamification; they should be "clear, concrete, actionable learning tasks" (Dicheva *et al.*, 2015, p. 78). Moreover, challenge is crucial to effectively motivate players (Kapp, 2012), and encourages active discovery and experiential learning (Faiella & Ricciardi, 2015; Perrotta et al., 2013).

In this study's gamified orientation day, students solve problems and complete challenges, to retrieve clues on the mysterious economist (goal of the game). Students are offered a different challenge at each of the ten stations, located across the faculty. Every station is organised around a certain theme characterising the first-year student transition, including the course schedule, curriculum, student societies, library, student counselling. At a station, students first solve a problem or complete a task linked to the orientation process (e.g., ordering books, subscribing to student counselling). Station tasks vary in length and difficulty. After task completion, students receive a reward: a clue on the economist's name. Each station thus consists of an orientation part (learning task linked to university transition) and a game part (reward to reach the game objective). However, the first challenge students face during the orientation day is not yet linked to a specific station. After watching the video which explained the goal of the game, each team first must solve a puzzle to receive their folder with

game information. This first challenge, which all groups complete at their own pace, assures that not all teams begin the game route simultaneously.

2.6 Feedback and rewards

Another essential trait is feedback that "tells players how close they are to achieving the goal … [it] serves as a promise to the players that the goal is definitely achievable and it provides motivation to keep playing" (McGonigal, 2012, p. 21). Feedback should be informational, instant, clear, and frequent (Kapp, 2012; Domínguez *et al.*, 2013). Moreover, it should be formative in nature, to facilitate players' competence satisfaction and evoke the desired actions and performance (Perrotta *et al.*, 2013; Sailer *et al.*, 2017). In this study's gamified orientation day, students can continuously ask staff members for informal and direct feedback. At every station, staff members guide each team through the orientation task and reward them with the clue on the mysterious economist. Moreover, students can always ask additional questions or feedback to staff members at a central station.

Rewards should have a meaningful link to the goal of the game: "if a reward provided for a task is seen as informational, then it will make one feel competent and in control, leading to higher intrinsic motivation. If a reward is seen as controlling, it makes one feel powerless and incompetent, decreasing intrinsic motivation" (Hanus and Fox, 2015, p. 153). In this study's gamified orientation day, if students successfully complete a station task, they receive a reward that is a clue to achieve the goal of the game. Furthermore, when handing in their definitive answer, students receive a university goodie bag. This reward is for all students, not only those who got the answer right (social comparison and destructive competition are avoided, cf. Section 2.1). One week after the orientation day, during class time, the winning team is announced.

2.7 Safe environment

Gamified learning should provide students with a safe environment, allowing them to make mistakes without consequences or judgement (Faiella and Ricciardi, 2015). This freedom to fail entails that students are more engaged and perceive less pressure to perform (Apostol, Zaharescu and Alexe, 2013; Hanus and Fox, 2015). A safe environment is especially relevant for orientation activities, as first-year students typically enter university with socio-emotional and practical insecurities (Conley *et al.*, 2014). Orientation activities should facilitate a welcoming environment and informal contacts with approachable staff members (Vinson *et al.*, 2010). This study's gamified orientation day aims to enable a safe environment, considering both the game purpose and the orientation purpose.

Considering the game itself, there is no pressure to perform, and all teams start on equal grounds. The difficulty level is attainable, making students feel competent and motivated. Moreover, staff members are present throughout the game to help students. Fun prevails over performance, reducing nervousness. Regarding the orientation purposes, learning goals are set to reduce insecurity with first-year students and to prepare them for their weeks at university. The different stations offer students information and tasks crucial to their university adjustment. Staff members (e.g., professors, assistants, student counsellors, library staff) and senior students are omnipresent during the orientation days, creating a sense of community. Following different learning tasks, students will feel well prepared to start their university journey and will have more certainty on what to expect during the first weeks. Therefore, they will feel less "lost" in the first weeks at university, as they already know the faculty building and some peers.

2.8 Sense of mastery

Gamification enables players to obtain a sense of mastery by successfully completing challenges, which "has a positive impact on the user's self-esteem, offering them feelings of satisfaction and accomplishment" (Apostol, Zaharescu and Alexe, 2013, p. 68). Similarly, Kapp (2012) argues that a sense of mastery should be central to gamified learning: a focus on mastery of the goal is imperative, players should be visibly recognised for their accomplishments, and this recognition should only depend on player's own achievement, not of others. The 'sense of mastery' element is also closely related to the need for competence (feeling of ability and progression) in light of the SDT (Bai et al., 2020; Manzano-Léon et al., 2021; Sailer et al., 2017).

This study's gamified orientation day aims at strengthening students' sense of mastery regarding both the game, and their university transition. First, regarding the game objectives, the difficulty level makes it attainable to find the right solution. As staff members offer continuous feedback and affirmation across the different stations, students gain self-confidence on their game performance. Second, the orientation day aims to ease students'

university transition, facilitating their adaptation to the educational environment and the student community. The orientation day enables students to start their university journey more confident, as they get to know fellow peers, faculty buildings, and university staff, while actively processing information on the academic expectations and procedures.

3. Methodology

3.1 Participants

This study took place in different first-year undergraduate study programmes at the Faculty of Economics at a large Western European university. The orientation day was organised for the faculty's different undergraduate study programmes: business administration (SP_1), business economics (SP_2), and public administration (SP_3).

The orientation day was organised and studied during two consecutive years (Y_1 and Y_2). Each session was organised on campus in the week before the semester starts, for max. 300 students, and takes approximately 2.5 hours. Table X presents the number of students who participated in the orientation day. Furthermore, data was collected through a survey at the end of the orientation day. This survey contained several close-ended and open-ended questions. In total, 1806 students completed the survey and therefore evaluated the orientation day. Although completing the open-ended questions was voluntary, 1326 students filled in at least one open-ended question, and thus provided qualitative data to evaluate the orientation day. Consequently, this sample of 1326 students will be further examined in the qualitative data analyses. Table 1 depicts several figures: the number of students participating in the orientation day, the number of students filling in the survey (open-ended and/or close-ended questions), and the number of students filling in at least one open-ended question (i.e., sample size of this study). The response rate comprises the sample size in proportion to the participating students. In total, 63% of the students who participated in the gamified orientation day, provided qualitative data through the survey.

Orientation day participation is not obligatory for first-year students; no evaluation is linked to their orientation day performance. Nevertheless, official university communication strongly recommends all enrolling first-year students to participate. Therefore, most students are assumed to have participated.

Table 1: Sample composition

Year		SP_1	SP_2	SP_3	Total
Y_1	Participants	454	469	63	986
	Filled in survey	392	445	60	897
	Sample size (*n*)	**293**	**353**	**51**	**697**
	Response rate	65%	75%	81%	71%
Y_2	Participants	562	483	77	1122
	Filled in survey	406	427	76	909
	Sample size (*n*)	**257**	**303**	**69**	**629**
	Response rate	46%	63%	90%	56%
		SP_1	SP_2	SP_3	Total
Total	Participants	1016	952	140	2108
	Filled in survey	798	872	136	1806
	Sample size (*n*)	**550**	**656**	**120**	**1326**
	Response rate	54%	69%	86%	63%

3.2 Data collection and data analysis

Data were collected and analysed in Y_1 and Y_2 of the study. At the end of the orientation day, students were requested to fill in a survey with several close-ended and open-ended questions. The latter resulted in qualitative survey data, by which the orientation day can be evaluated. The open-ended questions explicitly asked students

what they liked and disliked about the orientation day. All data are anonymous. Qualitative data are inductively analysed using NVivo, following the thematic analysis methodology (Braun and Clarke, 2006), by two independent researchers.

4. Results

Inductive thematic coding revealed the main advantages of the gamified orientation day, and suggestions for improvement. In total, 1195 students (90% of the sample) mentioned one or multiple positive traits (advantages) of the gamified orientation day, whereas 546 students (41% of the sample) mentioned a negative trait or suggestion for improvement. Themes raised by less than 40 individual students will not be further discussed. Note that one individual student can have addressed multiple advantages or suggestions. Figure 1 presents the most common advantages.

First, 467 students (35%) explicitly stated that they found the orientation day a nice and welcoming experience: "The gamified orientation day was nice and pleasant. It reduced my stress level" (S1580), "I feel good, I now have more clarity on what will be expected of me at the university" (S608). Second, 382 students (29%) expressed that everything was well explained and that they perceived the orientation day as very informative and useful: "The different stations with information were excellent, the explanation was very clear" (S3). Third, 315 students (24%) appreciated the social aspect of the orientation day: meeting peers and working together: "Very fun way to get to know new people" (S1234), "It's like a small team building to get to know your peer students better" (S1419). Fourth, the game aspect was acknowledged by 285 students (21%): "The game was certainly an added value for the orientation day" (S153), "Lovely that the 'boring' administrative tasks were incorporated in a game" (S674). Another advantage, described by 185 students (14%), is exploring the campus: "Pleasant way to discover the faculty" (S1731). Moreover, 134 students (10%) valued the originality and novelty: "I didn't expect it to be such a great and interactive orientation day. I'm pleasantly surprised" (S1759). Furthermore, 134 students (10%) acknowledged the framing of the game and the game components (e.g., task per station, quest). Additionally, 97 students (7%) expressed their satisfaction on actively participating, rather than just having to listen to a plenary presentation. 67 students (5%) explained that the orientation day was very well organised, and 66 students (5%) appreciated the crew's support and feedback. More generally, 60 students (5%) mentioned to perceive the orientation day as a 'good introduction', and 50 students (4%) described to 'appreciate the idea'. Finally, 57 students (4%) enjoyed meeting the student associations and student unions at the orientation day.

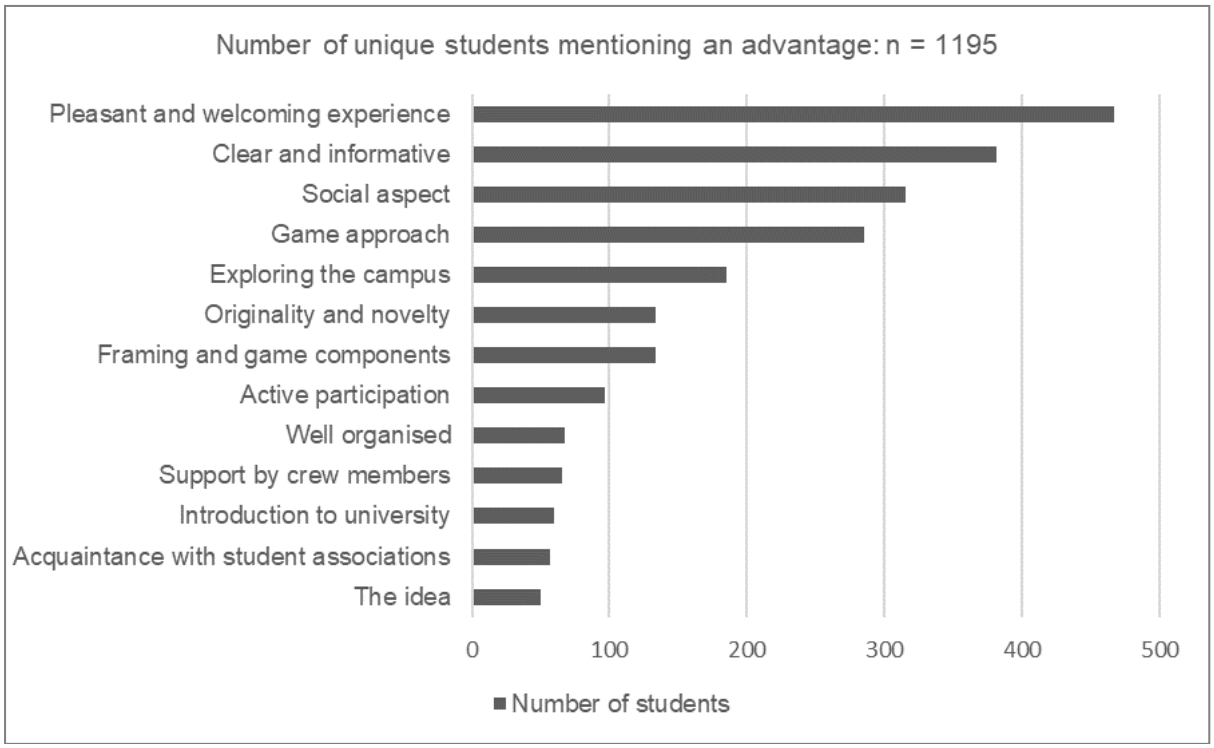


Figure 1: Student-expressed advantages

Figure 2 presents several themes of suggestions, by which students feel like the orientation day can be improved. Primarily, 241 students (18%) mentioned that the orientation day took rather long: "It took quite a while, but we enjoyed it nevertheless" (S107). This suggestion was driven by the sometimes inaccurate communication regarding the timing: "Provide more time and indicate this correctly in advance" (S70). Moreover, 98 students (7%) expressed that they sometimes had trouble knowing what was exactly expected: "Sometimes it was a bit unclear, but there were many crew members to help us out" (S559). Additionally, 65 students (5%) found the game aspect rather unnecessary: "The framing of the game was nice, but no added value" (S407). Furthermore, 54 students (4%) mentioned that they would have appreciated more detailed explanation on the course of the game, especially at the start. Finally, 46 students (3%) found that the orientation day focused very little on informing students regarding the factual information on the university.

Note, that students predominantly offered suggestions in addition to perceived advantages. Moreover, although the survey explicitly tried to elicit suggestions, 223 students – 17% of the sample – answered that they did not want to change anything about the gamified orientation day.

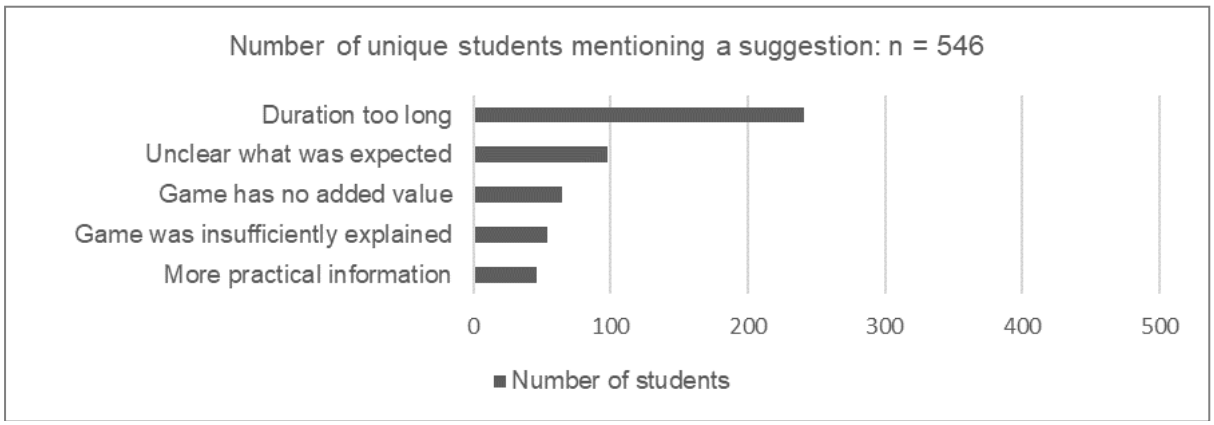


Figure 2: Student-expressed suggestions

5. Discussion

This study offers a strategy to facilitate students' transition to higher education, by presenting a theoretically founded gamified orientation day. The results indicate that this orientation day enables students' social and academic integration. Students are very enthusiastic about the gamified orientation day, resembling the conclusions of, among others, Bai, Hew and Huang (2020). An essential benefit of the gamified orientation day is that it stimulates students to collaborate and create social connections. Costa, Viana and Raleiras (2021) also confirmed that students have a strong 'desire for sociability' and particularly appreciate peer collaboration during gamified learning settings.

The identified strengths of the gamified orientation day relate to the aforementioned features of Apostol, Zaharescu and Alexe (2013); these entail the principles on which the orientation day was designed. Generally, the game approach was highly valued, implying the interplay between the eight features of Apostol, Zaharescu and Alexe (2013). Other student-expressed advantages can be linked to particular features. First, students find the orientation day a pleasant experience; the *story* might create engagement, a *safe environment* makes students feel welcome and secure, and a *sense of mastery* enables confidence and satisfaction. Second, students positively perceive what is explained, and the expectations towards them. This might be due to the *rules*, the stations in which *problem solving* is central, and the staff offering continuous *feedback* and a *safe environment* to ask questions. Third, students appreciate the social aspects of meeting peers and working in teams, which are clearly related to the *players* feature. Fourth, students are encouraged to explore the faculty as part of the game's *goal and clear outcome,* and the ensuing *problem solving*. Moreover, the faculty serves as a *safe environment* to the students. Fifth, the framing and creativity of the game design relates to the *story*. Finally, students were satisfied on the staff's support and the presence of student associations, which again concerns the *safe environment* and *feedback*.

The data comprised more positive than negative feedback; nevertheless, the students' suggestions should also be discussed. Several students would prefer the orientation day to take up less time; others perceived the

explanations insufficient, or felt uncertain about what was expected. Correspondingly, Costa, Viana and Raleiras (2021) recommend that 'the rules of the game' should always be explicit and clear, to avoid practical uncertainties or inaccurate assumptions of participants. Furthermore, the criticism on the game not being an added value to the orientation day, relates to the findings of Bai, Hew and Huang (2020): notwithstanding students' general enthusiasm on gamification, a minority does not believe in its additional utility.

The current study contains some conceptual and methodological limitations. First, this study does not include an experimental design (with control group) to evaluate the effect of the orientation day on students' university transition, which is interesting to further explore. Second, to ensure the novelty effect, students were not offered the possibility to choose between a gamified and a traditional orientation day. However, research has demonstrated that gamification is even more engaging and motivating when students have actively chosen to participate in the gamified learning setting, in line with students' need for autonomy (SDT) (e.g., Sailer *et al.*, 2017; Bai, Hew and Huang, 2020). Third, this study's data analyses demonstrated students' overarching evaluation of the gamified orientation day. Nevertheless, some authors recommend to "investigate specific elements of gamification rather than as an overarching concept so that the effectiveness of different mechanics can be parsed out" (Hanus and Fox, 2015, p. 160). Therefore, it would be interesting to additionally capture students' evaluations by, either more focused quantitative data to assess the effectiveness of the different gamification features, or in-depth interviews to understand students' perceptions in more detail. Despite several opportunities for complementary research, this study provides compelling insights on the gamification of an orientation day and intends to inspire other universities in rethinking their orientation strategies to ease the transition of first-year students.

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Inclusive AR-games for Education of Deaf Children: Challenges and Opportunities

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Abstract: Game-based learning has had a rapid development in the 21st century, attracting an increasing audience. However, inclusion of all is still not a reality in society, with accessibility for deaf and hard of hearing children as a remaining challenge. To be excluded from learning due to communication barriers can have severe consequences for further studies and work. Based on previous research Augmented Reality (AR) games can be joyful learning tools that include activities with different sign languages, but AR based learning games for deaf and hard of hearing lack research. This paper aims to present opportunities and challenges of designing inclusive AR games for education of deaf children. Methods involved conducting a scoping review of previous studies about AR for deaf people. Experts were involved as co-authors for in-depth understanding of sign languages and challenges for deaf people. A set of AR input and output techniques were analysed for appropriateness, and various AR based game mechanics were compared. Results indicate that inclusive AR gameplay for deaf people could be built on AR based image and object tracking, complemented with sign recognition. These technologies provide input from the user and the real-world environment typically via the camera to the app. Scene tracking and GPS can be used for location-based game mechanics. Output to the user can be done via local signed videos ideally, but also with images and animations. Moreover, a civic intelligence approach can be applied to overcome many of the challenges that have been identified in five dimensions for inclusion of deaf people i.e., cultural, educational, psycho-social, semantic, and multimodal. The input from trusted, educated signers and teachers can enable the connection between real world objects and signed videos to provide explanations of concepts. The conclusion is that the development of an inclusive, multi-language AR game for deaf people needs to be carried out as an international collaboration, addressing all five dimensions.

Keywords: Deaf, Sign language, Game-based learning, Augmented reality, Accessibility

1. Introduction

The development of games and game-based learning in the 21st century has been a fast and broad process. With the two categories of hardcore games and casual games combined digital games are attracting a large part of the population (Juul, 2010). However, inclusion of all is still not a reality in contemporary society, with accessibility for deaf and hard-of-hearing (DHH) people as one of the remaining challenges (Costello, Lambert & Kern, 2019). To be excluded from learning due to communication barriers can have severe consequences for deaf persons, for further studies and work. According to the principle of 'Education for All', DHH students should not be excluded from mainstream education (Ibrahim, Alias & Nordin, 2016), and with the ongoing development educational games are gradually being integrated into mainstream education.

In order to create learning games accessible for DHH people, game developers should make an effort to present the content of acoustic inputs in a deaf-friendly visual modality. Two possible solutions that might be useful to overcome language and communication barriers are the implementation of written text and sign language translation into the game design. Both of them are accessible to DHH people in that they can be perceived through an intact sensory modality (i.e., sight) and do not rely on the acoustic modality. However, as extensively discussed in Mantovan et al (2016), an important difference should be highlighted.

A written text is a visual representation of an auditorily-based language system, which by nature requires hearing to trigger spontaneous language acquisition. Overall, the competence level in a spoken language does not appear homogeneous within the DHH population, with several factors being involved: degree of hearing loss,

onset age, use of hearing aids or cochlear implants and so on (Swisher 1989). Despite being (apparently) fully accessible to DHH people, written texts pose a challenge to many of them who do not have a native competence in the lexicon and grammar of the spoken language. This is even more true for DHH children who are still in the process of language learning and are likely to struggle with text comprehension more than adults. Also, inputs in written form do not transmit information provided by intonation and other prosodic features, which may result in a sort of emotional detachment from the contents of the game.

On the other hand, sign languages are full-fledged natural languages expressed in the visual modality. A common misconception is that sign languages are somehow parasitic to spoken languages, but this is not the case as languages in the two modalities have independently emerged and evolved through the spontaneous interaction of the members of their communities. More than sixty years of scientific research on sign languages have demonstrated that they display the same level of linguistic complexity that has been observed in spoken languages (a.o. Sandler & Lillo-Martin 2006; Brentari 2010). Abstract linguistic structures are realised through two manual articulators (i.e., the hands) and a number of non-manual markers including facial expressions, movements of the head and shoulders. Because of their visual nature, sign languages under appropriate exposure can be fully acquired by DHH individuals in an effortless and spontaneous way. Sign language inputs may be integrated in a learning game basically in two ways: through video-recordings of human signers or the manipulation of virtual signing characters.

Augmented reality (AR) games provide opportunities for designing joyful learning in educational settings with different sign languages for DHH children, but there are also several challenges. Many studies have been conducted about AR games for learning and for DHH people but studies about AR-based educational games for DHH and especially deaf children seems to be a gap in current research or is at least less researched. This paper aims to present challenges and opportunities for the design and development of inclusive mobile AR-games for education of DHH children based upon current research.

2. Methods

Design science research (DSR) combines design and scientific study of artefacts to enable people to overcome challenges or realise opportunities (Johannesson & Perjons, 2014). While this study does not create such an artefact directly, the more long-term purpose is to enable a development of inclusive educational AR-games for DHH children. The DSR method framework by (Ibid.) includes several activities where this paper focuses on explicating problems. A scoping review of previous studies about AR for DHH people was conducted to create an overview of the selected area as described by (Munn et al., 2018). Scoping reviews have been recommended as an appropriate approach to explore a complex or heterogeneous field of knowledge (Mays, Roberts & Popay, 2001; Pham et al., 2014), and relevant for studies with the purpose of identifying knowledge gaps and clarifying concepts. Scoping review offers a method to gather key concepts in a specific research field, and to identify the main sources for future work. (Munn et al., 2018).

Searches were done during December 2021 to May 2022 using Google Scholar. The main query was created with *allintitle: "augmented reality" +deaf* with no limitations of publication year to find studies specifically for deaf. Also, by only including papers with the search string in the title ensured that each paper had a clear focus on these search terms. To widen the scope for related research in an extended search, the +deaf term was replaced by +accessibility, +accessible, +disabilities, +disability, +impairment, +impairments, +impaired in individual searches. From the extended search, only papers that focused on DHH people were included. Further exclusion criteria were that papers must be published research. Moreover, to better understand the target group of DHH players, involving experts in sign language as well as about education for DHH people as co-authors was required.

Also, a set of potential AR input and output techniques were analysed for appropriateness based on a unified method for universally accessible games (Grammenos, Savidis & Stephanidis, 2007). The appropriateness analysis compares potential input/output options with user characteristics, and evaluates if each option is ideal, appropriate, could be used, inappropriate or neutral.

3. Findings and Discussion

3.1 Scoping review of AR for DHH people

From the scoping review it was found that Augmented reality for DHH people has been recently explored in studies for various purposes. Quintero et al (2019) conducted a systematic review of AR for inclusive education,

with some studies about DHH, and Quintero et al (2021) suggested a method for co-creation of AR content using principles for universal design learning. This paper focuses specifically on AR studies for DHH people. An early study about mobile AR for DHH people was made by Parton et al (2010) using 2D barcodes and Youtube videos created by teachers themselves, to create an affordable and feasible AR-based teaching experience with early smartphones. Today, QR codes are more often used but the basic idea remains to link the physical world to virtual objects like online videos. More early studies were conducted by Zainuddin et al (2010a, 2010b) creating a dual language AR Book for teaching, where text (in Bahasa Malaysia and English) in the book was complemented by sign language videos via AR and 3D-models in AR for illustration. Al-Megren & Almutairi (2018) created a mobile AR app for learning of ArSL by mapping printed words to corresponding signs, which was shown to be more effective compared to traditional teaching approaches using ArSL, pictures and fingerspelling with 20 participants divided in two groups.

Ridha & Shehieb (2021) created a solution with real-time transcription, speech emotion recognition, sound indications features, as well as classroom assistive tools, using an affordable set of AR glasses. Falletto, Prinetto and Tiotto (2009) suggested a system for signing virtual characters. Cadeñanes Garnica & Arrieta (2014) presents a mixed reality (desktop, tablet and head mounted AR) toolset to teach fingerspelling with animated virtual characters and a physical sign-language book and provides insights into how different mixed reality modalities can be used for teaching fingerspelling. Cadeñanes & González Arrieta (2014) also developed a Sign Language Teaching Model (SLTM) called Multi-language Cycle for Sign Language Understanding (MuCy), a continuous psychomotor cycle for teaching sign language and fingerspelling using AR virtual characters with printed books.

Mirzaei, Ghorshi, & Mortazavi (2012a) presents an AR system with two modes: 1) automated speech to text and 2) facial expression to handle noisy environments where speech recognition can be hard. The text was presented on a mobile AR display to communicate with hearing people. Mirzaei, Ghorshi, & Mortazavi (2012b) added text-to-speech to the system. Dabran et al (2017) also combined AR with speech recognition to create real-time subtitles so hearing-impaired people can access live talks. In a similar vein, Ioannou & Constantinou (2018) used head mounted AR with an adolescent student with cochlear implant while communicating with teachers and tablet AR with four six-graders to learn vocabulary and improve reading skills. The communication was shown on the AR glasses screen (for the student) and on a smartphone (for the teacher). Luo et al (2022) created a synchronous sign language translation visualisation interface for head-mounted AR called Avatar Interpreter to be used in classrooms.

What emerged from this scoping review is that written texts may be implemented in an AR system for DHH people to fulfil two main functions: enhance access to contents and support spoken language learning. Since the linguistic competence in the spoken language is highly variable among the DHH population (a.o. Howerton-Fox & Falk 2019), the use of written texts may be effective to different degrees and some strategies of text adaptation may be used.

3.2 AR Game mechanics for education

There have been a significant number of studies about AR for learning. Based on a literature review by Li et al (2017) almost half of the studies found AR to be more engaging than traditional learning and more than half found AR games to be fun, interesting, or enjoyable. Based on Li et al (2017) AR game mechanics for learning are collaboration and interaction with face-to-face communication, group solving tasks, competition and sharing experiences, between students but also between students and teachers/parents. The latter had been less explored. A limitation of games was time so the activity can fit within the school schedule. Quizzes, puzzles and story-based games were most popular. Collection of items and role play were also fairly common. Quests and exploration were less common. Technically, location and image recognition were the most common inputs, whereas object recognition was used in some games. Gestures were also mentioned. (Ibid.) Face recognition was not mentioned but this may be due to issues of personal integrity for students.

3.3 Challenges for accessibility and representativeness of DHH people

The development of accessible AR games for DHH people involves several challenges related to Sign Language and DHH culture. The contribution we bring here is based on the experience obtained in two Portuguese R&D projects involving the development of video games accessible to the DHH: an online repository that integrates 26 bilingual mini-games, and GBL4deaf where the video game "Space adventure: Defend the planet!" was developed (educacaoacessivel.ulusofona.pt/en/ and gbl4deaf.ulusofona.pt/thegame/ respectively). The

following analysis is organised into five distinct dimensions: Cultural, Educational, Psychosocial, Semantic, and Multimodal.

Cultural dimension: The involvement of a DHH signer is key for the game to be welcomed by the DHH community. If we think that we are developing content in the native language of the DHH person, it becomes obvious the need to have a native person in that language for reasons of linguistic accuracy. However, at least in the case of the Portuguese reality, it is also a matter of representativeness and involvement of the DHH in the creation of a content that is intended for them. The DHH community wants to participate in the development of content that is addressed to them, in order to not only ensure linguistic accuracy but also that this same content is consistent with the vision and understanding of the world of the DHH person.

Educational dimension: In order to translate a concept correctly into a sign language, the signer must understand it in the first place. Translation from one language to another (regardless of modalities such as spoken or sign language) requires an accurate understanding of the original message. Also, the translator should be aware of the context in order to correctly express meanings from one language to the other. Thus, in the case of spoken or written content (from a non DHH author), it is crucial to involve: the hearing author of the content, the DHH signer, and the Sign Language interpreter. This will be potentially time consuming in the case of complex or abstract content, but essential for the accuracy of the message in sign language.

Psychosocial dimension: The DHH signer must trust the sign language interpreter. Although the DHH signer may have lipreading and text interpretation skills, when concepts are more complex or have been forgotten, a dialogue between the specialist or author of the topic in question will always be necessary to fully understand the message and its context. In this question-and-answer process, the DHH signer is largely dependent on the interpreter's ability to understand the content in question. If this first level of comprehension fails, the sign language message is irreparably compromised. Beyond this crucial point, the DHH must recognize the interpreter's fluency and accuracy in sign language. If this is not the case, a principle of distrust that is difficult to overcome will be established right from the start. Another important aspect is empathy between the DHH person and the interpreter which, although not essential, will certainly facilitate the process and the quality of the work.

Semantic dimension: Generally speaking, sign languages are less standardised than spoken languages. They tend to show a higher degree of linguistic variation due to various socio-linguistic factors (e.g. lack of written form, atypical language acquisition and transmission, paucity of bilingual programs, absence of TV shows in sign language). On top of that, subject-specific signs show even more variation for two reasons: i) sign languages are not typically used to teach subjects at school and ii) not many native signers have achieved a degree in some particular fields. In the specificity of the subjects, it may be hard to find the corresponding technical signs, so an alternative strategy could be fingerspelling (spelling the word with the manual alphabet). This option not only compromises the visual fluidity that underlies sign language, but also conditions the understanding of the message to the knowledge of the word in question. The message then becomes substantially more complex, making comprehension extremely difficult, which, in the case of a child, will be even more problematic given the shorter attention span that is characteristic of children. What happens in Portugal in this regard, are the schools and their teachers who create gestural codes that only work in that school. Therefore, if a DHH student changes schools, they will probably encounter signs that do not correspond to what they have learned. The recognition of the new sign as an "official sign" is the result of a slow process of dissemination by the DHH community, and there is no official entity that defines and validates these signs.

Multimodal dimension: Signing has proper grammatical rules, is typically done in combination with facial expressions and signing itself is complex. These three characteristics of sign language are very complex challenges to overcome through technology, such as "digital interpreters" in the form of virtual characters. Despite all the effort and evolution that has been made in this field, these challenges have yet to be fully resolved. What is at stake is the accuracy of the handshape, location, movement, and orientation of the hands, as well as the association of facial expressions and the fluidity of the message. As said before, a correct interpretation of sign language needs the signer to understand the context in order for the sign to be properly applied. Words (written or spoken) can have a recurring double meaning that has to be constantly checked in its context. Its passage into sign depends on this understanding, otherwise the sign will appear isolated and meaningless. In sign language, this ambiguous dimension is reinforced by the intensity of the sign and facial expressions, which can give very different meanings to the same sign. Given the challenge and the examples we

are aware of, it seems safe to say that virtual character sign language interpretation is a technology with a long way to go.

3.4 Opportunities of AR for DHH people

Automated systems like signing virtual characters and automated translation between sign language and voice has limited use due to conflicts with all five dimensions. To overcome some of the challenges with the five dimensions, civic intelligence (CI) is a promising opportunity where a community of trusted persons can provide content. One example was explored by Parton, Hancock, & Dawson (2010). Videos of trusted, DHH signers in different languages, who are knowledgeable in different subjects can potentially volunteer and upload explanations of concepts, especially those that do not have a direct language correspondence. An existing platform like Youtube or similar can make it cost effective and easy to implement (Ibid.). This CI-based video approach has potential to fit within all dimensions: the signer is DHH, knows the subject or concepts (self-reported), can handle the semantics in local languages, and include both signs and facial expressions of a real person. The potential of trust can be harder to achieve, but a ranking system (Hoisl, B., Aigner, W. & Miksch, 2007; Ling et al, 2005) may help other users to know who are the best signers for a specific subject/topic and language, and promote more volunteers. An opportunity with image recognition is to link e.g., maths formulas to a set of CI videos explaining it similar to (Parton, Hancock, & Dawson, 2010) in the local sign language (Zainuddin, Zaman, & Ahmad, 2010a) for the student. Similar solutions can also be done for other subjects, for instance with books, questions and other material within curricula could be linked to CI videos. The links can also be provided with CI either by signers but also by teachers (Parton, Hancock, & Dawson, 2010). A multimodal approach is also possible and preferred (Al-Megren & Almutairi, 2018; Cadeñanes Garnica & Arrieta, 2014) for inclusion together with non DHH people. Object recognition is another AR technology to detect three-dimensional objects in the environment either with a (depth) camera or light detection and ranging (LiDAR). Object recognition can also be combined with civic intelligence and/or machine learning to (semi)automatically tag or label objects with a description. In an educational context it may be used in more hands-on situations, for instance in a lab, a workshop or sports setting, where CI video-based instructions can be found for different tasks that the teacher wants to communicate to the students to do. Machine learning may also be used by analysing CI created signed videos and ease the dissemination of locally created signs.

3.5 Appropriateness analysis of AR interface alternatives

Table 1 shows an appropriateness analysis (Grammenos, Savidis and Stephanidis, 2007) of possible input and output design alternatives in a generic educational AR game for different player attributes.

The columns in Table 1 represent potential input/output options to the AR application. The rows represent players attributes and the then user profiles, which is a combination of the individual attributes where the lowest value is selected. The table shows that Sign recognition is Ideal (input designed especially for DHH) while Image, Object and Plane recognition are all *Appropriate* input as DHH prefers visual mediums. However, if the DHH player is a novice player, Sign recognition may raise a barrier as it can be a learning curve for specific signs (hence *Could be used*). Some outdoor locations can be dangerous for children, thus deemed *Could be used* (if there is no alternative). Scene tracking is useful for larger objects, scenes, and also indoor environments with lack of GPS signals and cloud-based anchors can be added for multiuser AR game mechanics. For output, IS *Could be used* if there is no way to have a local sign language which would be *Ideal*. Images, Animations and Video are *Appropriate*. Based on this, two user profiles can be recommended: Novice (don't rely on sign recognition), Expert (sign recognition can be used for more advanced or efficient interaction).

Table 1: Appropriateness analysis and Player profiles

Abstract task: AR game interaction in inclusive learning contexts for DHH children

	Input (to the AR game)					Output (to the player)		
	Sign Recog-nition	**Image/ Object Recog.**	**Plane Detection**	**Indoor: Scene Tracking**	**Outdoor: GPS, Scene Tracking**	**Inter-national Sign, IS**	**Local SL**	**Images, Animations and Video**
Player attributes								
DHH	Ideal	Appropriate	Appropriate	Neutral	Neutral	Could be used	Ideal	Appropriate
Novice	Could be used	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Expert	Appropriate	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Child	Neutral	Neutral	Neutral	Appropriate	Could be used	Neutral	Neutral	Appropriate
DHH Children Player Profiles								
Novice	Could be used	Appropriate	Appropriate	Appropriate	Could be used	Could be used	Ideal	Appropriate
Expert	Appropriate	Appropriate	Appropriate	Appropriate	Could be used	Could be used	Ideal	Appropriate

4. Conclusion and future work

In this study five dimensions of challenges for accessibility and representativeness of DHH people have been defined, clarifying the requirements for signed videos in apps and AR games. Civic intelligence-based videos signed by DHH have been discussed as a potential opportunity to fit all five dimensions, contrary to using virtual characters. Appropriate AR input/output options for two child AR-player profiles have been defined including sign recognition, real world images/objects/planes, animations, local signed videos as well as location-based input. Texts and International Sign can be used as a complementary modality to local sign language.

The conclusion is that the development of an inclusive, multi-language AR game for DHH people needs to be carried out as an international collaboration. Firstly, there is a need for expertise regarding each national Sign language. Another is that the development of a high-quality AR game would also need a team with skills and knowledge in areas such as AR, accessibility, game design and narration. Using a Design Science Research framework (Johannesson & Perjons, 2014), the problem of overcoming the five dimensions of including DHH people and how to do that in a mobile AR game should be explicated. Secondly, the game design requirements should be defined with a user-centred approach. Thirdly, the game should be designed in a co-creation process involving teachers and experts from organisations for DHH people. Fourthly, the game should be distributed and tested in schools by DHH learners. A core design approach is user centred design. A challenge is to include DHH children in the co-design process, in accordance with “nothing about us without us”. This includes ethical considerations, especially to involve DHH children. Another challenge is how to create inclusive solutions and game mechanics that are appreciated by both DHH and non-DHH people. The design ideas presented in this study can be the basis for the design and development of an AR-game for DHH children in an educational context.

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Evaluation of Empirically Collected Feedback from a Simulation Game for Digitalised Production

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Abstract: Digitalisation causes a fundamental change in industrial production and brings new challenges for which employees in the manufacturing industry must be trained. A simulation game developed by researchers of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA supports this change process, from lean production to digitalisation in production through a game-based qualification. To evaluate how qualified employees are and to what extent they accept digital transformation, a quantitative survey was designed and filled out by the participants after each simulation game workshop. This paper aims to examine the mindset of different focus groups regarding their awareness of ongoing challenges concerning digital transformation. The survey results show that despite challenges due to the changes in production technologies and environments caused by Industry 4.0, the simulation game has generally contributed to a better understanding of the impact of digitalisation and the acceptance of the changes in production caused by the digital transformation.

Keywords: Simulation game, digital transformation, digitalised production, game-based simulation, evaluation

1. Introduction

The simulation game (Yesilyurt *et al.*, 2019) described here is integrated into the Future Work Lab (FWL) - the innovation lab for work, people, and technology of Fraunhofer IPA and Fraunhofer IAO in Stuttgart. The FWL (Issa *et al.*, 2018) is a research project funded by the German Federal Ministry of Education and Research (BMBF). It opened in 2017 and was in its second three-year funding period while collecting feedback during the simulation game. It is a platform that bundles numerous activities to research future production work. In this course, it also deals with production systems, the associated technologies, and how they will be innovated in the future.

Due to the diverse thematic approach of the FWL research project, a wide variety of different user groups need to come together. Especially in the interaction with the simulation game participants, the different views on Industry 4.0 specific topics become apparent, and other user groups bring a different level of experience and knowledge.

Industry 4.0 describes the fourth industrial revolution following the invention of the steam engine, industrialization, and the dawn of the computer age (Bauer et al. 2019). The specific term 'Industry 4.0' was first introduced in 2011 and is broadly published in Germany because of its strategic initiative status for the German federal government (Dombrowski, Richter and Krenkel, 2017), with which the digital transformation has gained more significant importance for the manufacturing companies.

The ongoing digital transformation in manufacturing companies leads to a wide variety of new digital solutions and applications introduced on the shop floor. They do not only have an impact on current working processes but also require new skills of the company employees (Pittich, Tenberg and Lensing, 2020). This results in a twofold challenge for a manufacturing company. On the one side, employees must learn how to deal with the new technologies; on the other side they must become familiar with the new processes (Bauer *et al.*, 2018). Both challenges bring about significant change for the workers. Hence, suitable change management for a significant fraction of the workforce is needed during the company's digital transformation. This includes a human-centric approach (Leyer, Richter and Steinhüser, 2019) results in a higher acceptance rate for the new digital solution. The term Human-centric means not only having the workers and their needs in mind but also helping them understand what will change with the new solution, why this change is necessary and what kind of benefits it brings to the workers. As presented and discussed in this paper, a simulation game can be a cornerstone for reaching this target.

Section 2 introduces the survey motivation for the simulation game. After that, the study design with the simulation game survey is introduced in section 3. Section 4 presents the collected feedback from different focus groups. The last section concludes with a summary, and overall critical appraisal of the focus groups' statements, highlighting future research plans for the simulation game.

2. Survey Motivation

New technologies support the company's vision of digitalised production, but they also entail a constant change through the deployment of new solutions. The simulation game is designed to sensitize participants to the current challenges of digital transformation and give them an understanding of the practical use of new technologies. After the successful execution of the simulation game, quantitative surveys (questionnaires) are handed out to the participants to get feedback on learning achievements, motivation, game organization, and execution.

The survey was performed with three focus groups: manufacturing company employees, works council representatives, and future qualified employees (FQE) (students). The manufacturing company employees are the employees on the shop floor with either equipment (manufacturing machines) or IT systems focus. Secondly, the works council representatives are employees on the shop floor who also work in a works council to protect the rights of the employees and support them in the internal company problems. Last, the FQE are university students and working students in the companies.

The survey's motivation is to investigate the differences of the focus groups in raising awareness of digitalised production with the simulation game and to comprehend the mindset of different roles and generations in the companies. The following section describes the survey design.

3. Study Design

All data were collected by hand, and no secondary, already existing data set was used. Therefore, the data collection for this paper can be characterised as the primary analysis. The data was collected through a survey in the format of a quantitative questionnaire in written form.

The paper follows a descriptive approach to describe the entirety of the respondents or group of respondents as precisely as possible about selected characteristics. The data acquisition can be characterised as a group study. However, this does not represent a comprehensive survey but only a sample of the people in the group. Also, it does not represent the entire group who completed the simulation game fully and partly because the feedback collection was only integrated later from the simulation game's executions between 14-12-2018 and 28-10-2021. Consideration should be given to the fact that the simulation game was only carried out to a very limited extent during the restrictions in force due to Covid-19. The number of participants hardly increased significantly during this period.

Likewise, the sample cannot be declared as a random sample selection. Therefore the sample must be classified as non-random and arbitrary. The reason for this is that not all potential participants have completed the simulation and provided feedback on it. The entirety of all potential participants would consist of the entirety of the defined and addressed target group. Accordingly, the results presented in this paper cannot be considered representative of entirety of the focus groups. The aggregated findings, representations, and statements presented here refer only to the sample that participated in the survey. Statements about the population of all potential participants of the simulation game, qualified employees with a manufacturing background, cannot be derived from this. Therefore, the formation of interference statistics is impossible, and the results presented here refer exclusively to the respondents.

A questionnaire in written form is used as the quantitative empirical survey. The raw data obtained from this was encoded using IBM SPSS Statistics (IBM, 2022). The resulting numerical data set was also analysed using SPSS and the available descriptive analysis methods.

The survey was created in two main categories. In the first category, the content of the simulation game was assessed. This category consists of 10 closed-ended statements. With the help of these statements, the learning outcome and the acceptance of the participants built up by the simulation game could be measured. The second category includes the assessment of the execution of the simulation game and contains 12 statements. The focus

of this category lies in the execution and organisation of the simulation game and the participants' motivation. The response options for the respective statements are all characterised by ordinal scales indicating the degree of agreement in the form of a ranking. The particular type of ordinal scale used here, a so-called Likert scale (Likert, 1932), has the same answer options across all statements:

- 1: Strongly agree
- 2: Agree
- 3: Neutral
- 4: Disagree
- 5: Strongly disagree
- No statement

The response options for the respective statements are all characterised by ordinal scales that indicate the degree of agreement in the form of a ranking. The mode and the median are given here as position parameters. Typically, no mean value can be calculated for ordinal scales. In this paper, the mean value is included. However, not for interpretation as an average value but rather to make a trend visible (Statista, 2022).

Table 1: Focus groups' information

Focus group	Number of workshops	Number of participants	Proportion
Manufacturing companies' employees	8	69	59 %
Work council representatives	3	32	27 %
Future qualified employees (FQE)	2	16	14 %

The simulation game is evaluated by 117 participants using the survey questionnaire. Table 1 visualizes the number of participants in the different focus groups. The collected data is further presented and analysed in the next section.

4. Study Results

As described in section 3, there were two categories of statements to collect feedback. The first group of statements was about the acceptance and reception of the technical content. The second group of statements addresses the execution and organization of the workshop - the letter E is added to the numbering of this group. Table 2 shows these two grouping statements.

Table 2: Study statements

Code	Statements
S1	Through the simulation game, I have understood what Industry 4.0 (digitalization) means and the principles behind it.
S2	The simulation game showed me the possible changes and opportunities caused by Industry 4.0.
S3	I believe that the simulation game has prepared me well for the future challenges of Industry 4.0.
S4	The simulation game concept helped me better assess my present and future situation.
S5	I realized that Industry 4.0 is based on already optimized processes (LEAN).
S6	The digitalised game round showed that Industry 4.0 makes processes more transparent.
S7	Digitalisation simplifies my work because the processes are structured with less paper.
S8	I have understood in which areas of my company Industry 4.0 has the most significant impact.
S9	The simulation game showed me how the variant-rich production could be supported by Industry 4.0.
S10	I will continue to practice the knowledge gained in the simulation game in the distant future.
S1E	The topic of the simulation game interested me.
S2E	The contents were explained in a comprehensible way.
S3E	The objectives of the simulation game were clearly defined.
S4E	The content structure of the simulation game was easily understandable.
S5E	I was motivated to think outside the box.
S6E	The simulation game encouraged my interest in the topic of Industry 4.0.
S7E	The content provided has an excellent relation to practice.
S8E	My expectations regarding the simulation game were fulfilled.
S9E	I have learned a lot from the simulation game.
S10E	The simulation game was well organized.
S11E	I was supervised well during the simulation game.
S12E	I can further recommend this simulation game.

Table 3 shows the recorded results for all statements in both categories. The coding of the response options to the statements corresponds precisely to the Likert scale given in section 3. The table shows the number of valid votes and the missing votes next to the codes for the respective statement. The mean, median, and mode are given as position parameters, while the standard deviation and variance are given as dispersion parameters. As already described, this is not an average in the sense of the arithmetic mean because this cannot be specified for ordinal scales. Instead, the aim is to be able to recognize a trend in the distribution of the answers. Thus, the standard deviation and the variance are not interpreted in the classical sense either. However, these were also applied because exemplary statements were selected for explanation with a high or low standard deviation.

Table 3: Study results

Code	Number of valid entries	Number of missing entries	Mean value	Median	Modus	Standard deviation	Variance
S1	116	1	1.86	2	2	0.768	0.59
S2	116	1	1.95	2	2	0.8	0.641
S3	116	1	2.47	2	2	0.774	0.599
S4	114	3	2.26	2	2	0.831	0.691
S5	115	2	1.82	2	2	0.79	0.624
S6	112	5	1.59	1	1	0.692	0.478
S7	116	1	1.84	2	1	0.913	0.834
S8	115	2	2.22	2	2	0.825	0.68
S9	116	1	1.84	2	2	0.802	0.643
S10	114	3	2.17	2	2[a]	0.861	0.742
S1E	117	0	1.38	1	1	0.57	0.325
S2E	117	0	1.46	1	1	0.65	0.423
S3E	117	0	1.52	1	1	0.651	0.424
S4E	117	0	1.44	1	1	0.594	0.352
S5E	117	0	1.74	2	1	0.835	0.696
S6E	116	1	1.8	2	1	0.794	0.63
S7E	117	0	1.82	2	2	0.795	0.631
S8E	116	1	1.84	2	2	0.768	0.59
S9E	114	3	2.28	2	3	0.955	0.912
S10E	117	0	1.49	1	1	0.677	0.459
S11E	117	0	1.36	1	1	0.594	0.353
S12E	117	0	1.4	1	1	0.573	0.329

Exemplary evaluations of the statements follow to gain more insight into the focus groups' feedback. Therefore, Statements with excellent and poor average values and statements with high and low standard deviations were selected and presented below.

Table 4: Statement S11E results

S11E		Strongly agree	Agree	Neutral	Sum
Category	FQE	81.25%	18.75%	0.00%	100.00%
	Manufacturing companies' employees	68.12%	24.64%	7.25%	100.00%
	Work council representatives	68.75%	25.00%	6.25%	100.00%
Sum		70.09%	23.93%	5.98%	100.00%

The statement (with an excellent mean value of 1.36) results in Table 4 show that approximately 94 % of the participants believe that they were supervised well during the simulation game. Only 6 % of the participants (especially manufacturing companies' employees and work council representatives) found the supervision satisfactory during the simulation game. This proves that the supervision of the simulation, independent of different focus groups, was in order for the general population of simulation game participants.

Table 5: Statement S1E results

S1E		Strongly agree	Agree	Neutral	Sum
Category	FQE	60.87%	34.78%	4.35%	100.00%
	Manufacturing companies' employees	71.88%	21.88%	6.25%	100.00%
	Work council representatives	65.81%	29.91%	4.27%	100.00%
Sum		65.81%	29.91%	4.27%	100.00%

Table 5 illustrates the results of the statement S1E (with an excellent mean value of 1.38). According to the results, approximately 96 % of the participants were interested in the topic of the simulation game. Only 4 % of the participants did not have much interest in the simulation game topic. This indicates that Industry 4.0 is an exciting topic for the general population of simulation game participants.

T**able 6**: Statement S3 results

S3		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	18.75%	50.00%	25.00%	6.25%	0.00%	100.00%
	Manufacturing companies' employees	7.35%	38.24%	44.12%	8.82%	1.47%	100.00%
	Work council representatives	6.25%	50.00%	43.75%	0.00%	0.00%	100.00%
Sum		8.62%	43.10%	41.38%	6.03%	0.86%	100.00%

The results of the S3 statement with a poor mean value of 2.47 were presented in Table 6. It is observed that about half of the manufacturing companies' employees and the work council representatives were satisfied that the simulation game has prepared them well for the future challenges of Industry 4.0. On the other hand, according to the statement's results, the simulation game helped prepare the FQE for the future Industry 4.0 challenges. It shows that they benefit more from the simulation game because they do not see the challenges in the same way as the more qualified employees in this simulation game's focus group.

Table 7: Statement S4 results

S4		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	62,50%	31,25%	6,25%	0,00%	0,00%	100,00%
	Manufacturing companies' employees	11,94%	41,79%	40,30%	4,48%	1,49%	100,00%
	Work council representatives	9,68%	48,39%	38,71%	3,23%	0,00%	100,00%
Sum		18,42%	42,11%	35,09%	3,51%	0,88%	100,00%

Statement S4 with a poor mean value of 2.26 (see Table 7), describes that the simulation game helped the participants to better assess their current and future situation regarding Industry 4.0. Two trends are observed here. While the FQEs answered this very positively, the response of the experienced employees for this statement was between 'agree' and 'neutral'. An interpretation can be that inexperienced participants learned a lot from the simulation game and answered this statement more positively than other focus groups. Nevertheless, in general, more than the majority of the simulation participants think they have a better assessment of their current and future situation after the simulation.

Table 8: Statement S7 results

S7		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Sum
Category	FQE	75,00%	18,75%	0,00%	6,25%	0,00%	100,00%
	Manufacturing companies' employees	50,00%	41,18%	7,35%	1,47%	0,00%	100,00%
	Work council representatives	12,50%	37,50%	34,38%	12,50%	3,13%	100,00%
Sum		43,10%	37,07%	13,79%	5,17%	0,86%	100,00%

Table 8 indicates the results of statement S7, which has the highest standard deviation. This high standard deviation was caused by the different opinions of the participants about the statement. On one side, after the simulation, most of the work council representatives have expressed their opinion that digitalisation does not simplify their work because the processes are structured with less paper. On the other hand, more than 90% of FQE and manufacturing companies' employees had the opposite opinion. Their results show that digitalisation helps the processes be structured with less paper, simplifying their work.

Table 9: Statement S12E results

S12E		Strongly agree	Agree	Neutral	Sum
Category	FQE	87,50%	12,50%	0,00%	100,00%
	Manufacturing companies' employees	56,52%	36,23%	7,25%	100,00%
	Work council representatives	68,75%	31,25%	0,00%	100,00%
Sum		64,10%	31,62%	4,27%	100,00%

The statement S12E results with the lowest standard deviation are indicated in Table 9. More than 95 % of the participants recommend this simulation game to others. Furthermore, only some participants from the focus group "manufacturing companies' employees" answered this statement with 'neutral'.

5. Summary and Outlook

This paper examines the mindsets of different focus groups concerning the ongoing challenges of digital transformation. First, the impact of the digital transformation in manufacturing and the human-centric approach are described. After that, the survey motivation is introduced. Then, the study design and focus groups are presented, and the response options for the respective statements are outlined. Furthermore, the simulation game's study results of the focus groups are indicated and interpreted.

The summary describes only the findings of the simulation game's study results with any assumptions of the authors. This is why the results presented in this paper cannot be considered representative of the entirety of the focus groups. The aggregated results, representations and statements shown here relate only to the sample that completed the survey.

To conclude the content of the simulation game from the questions, the primary distribution of the answers of the different focus groups was considered. In eight out of ten statements, the group of FQE most frequently choose the option 'strongly agree'. In the other two cases, the answer option was 'agree'. In the manufacturing companies' employees group, the answer 'agree' was selected as the most frequent response for each case in seven out of ten questions. Twice, the highest number of responses was for the answer 'strongly agree' and once for the answer 'neutral'. On the other hand, work council representatives choose the answer 'agree' as the most frequent response for nine of ten statements and 'neutral' once. The results show that compared to the other two groups the work council representatives evaluate the simulation game more critically. FQE responded most positively to the questions. This focus group was most likely to be confronted with new content in the simulation game because it could present content that had been discussed during the studies but had not yet been experienced in practice.

Next, the statement results of the focus group for the simulation games' execution show that FQE chooses the option 'strongly agree' in eleven out of twelve statements. Only the FQE responded to the S9E statement with 'agree'. This shows that FQE evaluated the simulation game execution much better than other focus groups. On the other hand, the manufacturing companies' employees selected the answer 'strongly agree' in eight out of twelve statements. Additionally, they answered three statements mostly with 'agree'; only in the S9E statement the most given answer was 'neutral'. The participants from the focus group work council representatives selected the answer 'strongly agree' mostly in nine out of twelve statements. They showed the same trend by answering survey statements as the manufacturing companies' employees since they answered two statements mostly with the option 'agree' and the S9E statement with 'neutral'. These results indicate that manufacturing companies' employees and work council representatives evaluated executing simulation positively. Only for the new learning content in the simulation game their opinions were more reserved than those of the FQE.

In the future, we will collect more data after the simulation executions to make the statements even more significant. It is planned to compare different mindsets of the focus groups in other countries. In addition, the simulation will be further developed, and an expansion with new elements has already been conceptualized (Himmelstoß *et al.*, 2021). After it is successfully implemented, we will collect feedback from participants and evaluate how it changes when new subject areas are addressed in the workshop.

Acknowledgements

The research described in this paper is part of the Future Work Lab (FWL) - the innovation laboratory for work, people and technology of the Fraunhofer IPA and Fraunhofer IAO in Stuttgart. It represents a platform that combines numerous activities for researching the production work of the future. It also considers production systems, associated technologies and how these will be innovated in the future.

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PhD Research Papers

Climate Adaptation as an Economic Challenge: Finding Business Strategies by Game-based Learning

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Abstract: Climate adaptation and learning support organizations in dealing with the current and projected consequences of climate change by recognizing challenges as opportunities, ensuring business continuity and increasing their economic efficiency. Here it applies that those actors who deal with their existing framework conditions, opportunities and risks at an early stage, and also have structures or capacities for strategic learning processes, increase their climate resilience and reduce their vulnerability to negative impacts. A cumulative doctoral thesis analyze to what extent companies already have climate-related structures conducive to learning, to what extent they take responsibility in terms of the learning object (climate change), and which elements prove to be limiting here. The results illustrate that intangible resources such as a sense of responsibility, executives positive attitude and common values have a significant influence on the way companies deal with climate change. Based on these findings, a serious game will be developed and its didactic effectiveness reflected critically to raise the climate-related awareness of decision-makers and to enable them to derive their own adaptation measures.

Keywords: Climate Adaptation, Organizational Learning, Game-based learning, Economic Efficiency, Serious Games, Change Management

1. Introduction

Increasing extreme weather events, political regulations, concurrent stakeholder interests and supplier assessments are just a few of the numerous impacts caused by the global climate change companies must deal with. Climate adaptation refers to the ability and volition to cope with external changes in a constructive manner, to anticipate future developments, and to continuously adapt internal processes to these changes (IPCC 2013). Moreover, the Intergovernmental Panel on Climate Change (IPCC) defines climate adaptation as an intervention to avoid economic damages while increasing economic effectiveness (IPCC 2013). Anticipatory and reactive adaptation measures, as well as associated changes in mind-sets, protect organizations from the actual and projected impacts of climate change. Profound climate adaptation characterizes a permanent process that takes place in a systemic way, which means involving the organization and its internal and external environment. Organizational adaptation, in general terms, encompasses the ability and volition to deal constructively with external changes, to anticipate future developments, and to continuously align structures and processes. Studies on climate adaptation frequently focus on the management level, as it is crucial for the resources and its implementation (Mahammadzadeh et al. 2013; Linnenluecke et al. 2013, Meinel/Höferl 2017; Meinel/Schüle 2018; Daddi et al. 2018). Much of the referred research focuses on identifying how organizations adapt to climate change and what structures can be conducive to learning (Bianchi et al. 2021; Nicoletti et al. 2019; Kanyama et al. 2018). Generally, climate adaptation and organizational learning is essential to serve organizations continued existence, development and competitiveness in the face of major transformations and expected external changes (Nicolletti et al. 2019; Feld/Seitter 2018; Cömlek et al. 2020).

To raise awareness among decision-makers, and to enable them to develop adaptation measures, it requires an innovative approach for knowledge transfer. Serious games represent an innovative approach to knowledge transfer and teaching (Susi et al. 2007) and support to foster cognitive, social and emotional skills (Greipl et al. 2020). Frederic Vester's environmental game 'Ecopolicy', published in 1978, was one of the first examples of an innovative didactic approach in the area of climate change. Here, economic and political actors develop an understanding of the simulated consequences and derive their own strategies (Vester 2021; Nguyen/Bosch 2014). Especially in the case of educational games, the entire context in which the game is intended must be considered to ensure didactic effectiveness (Subhash/Cudney 2018). Thus, the abilities and preconditions of the target group, as well as general conditions such as time, resources, volition, etc. must be considered. Gerber et al. (2021) analysed in their systematic literature review climate related game-based learning. Here the majority of games include, besides a specific goal and competitive character, also the element of collaboration among the players, who usually take on different roles. Finally, the required space for collaboration and reflective thinking is also emphasized in the work of Flood et al. (2018). Generally, the duality of formal knowledge transfer and experienceability of extreme events and strategies generates active learning and participation. In comparison to

classical teaching methods, the approach promises an enhanced ability to apply knowledge in practice (Hamari et al. 2016; Sousa/Rocha 2019).

Since there is still a lack of research regarding the interrelated learning processes among climate adaptation, this contribution is about a doctoral thesis which analyses to what extent climate adaptation is framed within an organizational learning (OL) process.

2. Methodology and initial findings of expert interviews and questionnaire

The research described above is linked to the development of two educational modules, see Figure 1. First, a regional study is conducted to analyze how companies in an industrialized Bavarian region already adapt to climate change, in how far they have climate-related structures conducive to learning and to what extent they take responsibility in terms of the learning object (climate change). Second, based on the results of the regional study, a serious game will be developed and evaluated. Here, different roles in a company react on simulated external conditions and initiate own adaptation strategies to experience its effects for their affiliated company. The target is to enable the players to derive individual adaptation strategies.

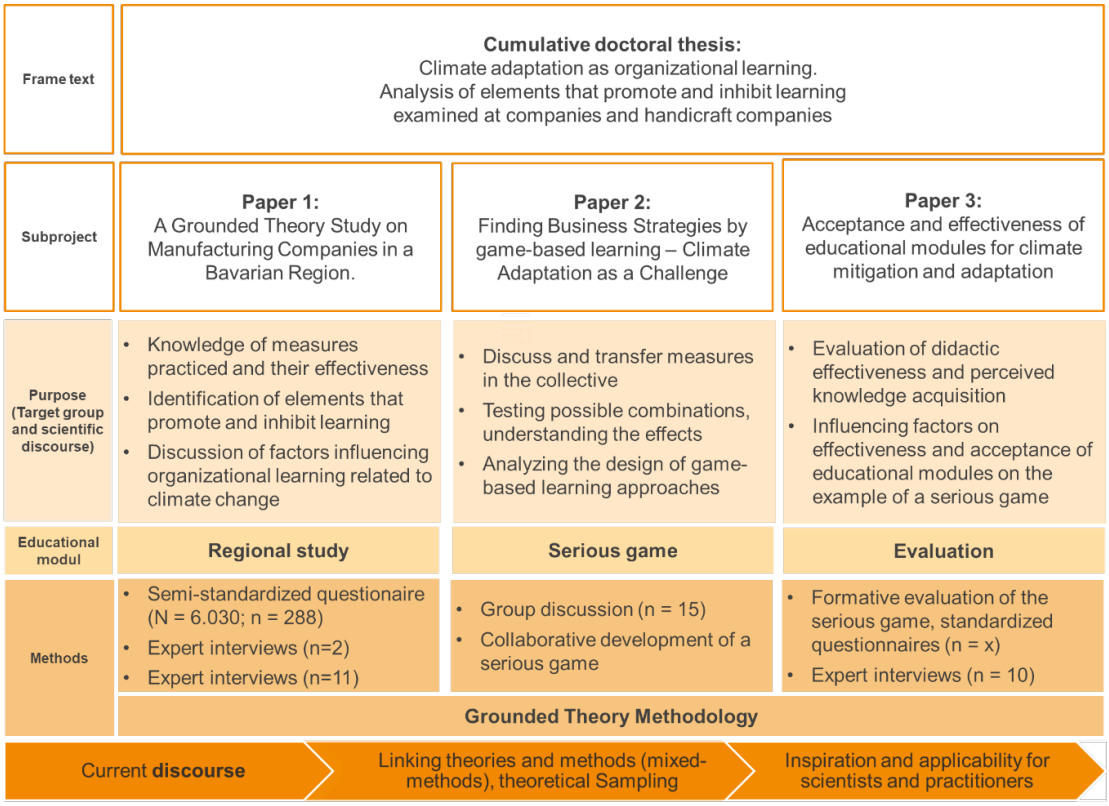


Figure 1: Conceptual design of the cumulative doctoral thesis with its three subprojects, own figure

To motivate and enable actors from companies to develop climate adaptation measures and to integrate these measures into the business strategies, it requires a target group oriented educational approach, which is addressed by the underlying research project. The PhD, started in June 2020, additionally analyses the inhibiting and enabling elements of a strategic learning process by carrying out several qualitative and quantitative studies (expert interviews, group discussion and semi-standardized questionnaires).

The conducted qualitative study of 13 expert interviews with manufacturing companies (Fischer et al. 2022) is based on the assumption that the issues of global climate change and climate adaptation are often still complex and abstract for companies outside the primary sector (e.g. example, agricultural sector). Applying Grounded Theory, we identified the core categories 'Economic efficiency', 'Dynamic organizational environment' and 'Change management', which interlink all interview findings. Summarizing the results, any form of climate adaptation is subject to the dogma of economic efficiency or the drive to preserve the organization. In this context, there are mostly smaller and larger barriers organizations have to face, e.g. amortization time, requirements from customers or regulatory aspects, which are to be considered before any implementation. At the same time,

appropriate knowledge is required to restructure processes, calculate measures and develop a suitable level of action by management. Further promoters are the employees who carry out the tasks themselves, and who pass on their practical experience and knowledge to decision-makers and report optimizations. It is confirmed that a general change in attitude is taking place in many companies. There is a consensus that a business as usual approach is not sustainable and not acceptable anymore.

In a subsequent study a total of 288 valid questionnaires were analysed, of which 52 were manufacturing companies, 80 non-manufacturing companies and 155 handicraft companies. The results indicate that the indirect impacts of climate change currently predominate. While these impacts involve a variety of fast-changing legal requirements, they also concern supply chain and raw material resources within supply chains. There is a rising awareness among the companies surveyed that suppliers make their manufacturing and sourcing processes more transparent, e.g., through supplier assessments. Generally, the entire sample already deals with climate change and especially intangible factors such as a sense of responsibility, leadership's positive attitude and common values have a significant influence on the way companies deal with climate change. One limiting factor here is that it cannot be clearly distinguished whether the structures conducive to learning, such as a positive error culture, innovation openness and an external network, are merely attributable to the issue of climate adaptation or are part of the fundamental 'organizational set-up'.

3. Implications for the game development

To find an adequate way of dealing with climate change as economic organizations, executives are initially required to develop a holistic approach with comprehensive measures for climate mitigation and adaptation, and to test them for their effectiveness and integrate them holistically. The preceding analyses already provided an actual overview of the companies' perception of climate change and how they are affected by it. Since no basic terminological understanding was assumed, there was no differentiation between climate mitigation and climate adaptation measures. Accordingly, the planned business game should focus on climate adaptation in manufacturing companies, since these companies have a high consumption of energy and resources (BMUV 2022). In cooperation with the target group, executives from manufacturing companies, the serious game 'MainKassandra' is developed, see Figure 2. Its content and didactic design follows the findings of the group interview with 6-7 executives, which is still to be conducted. Using this constructivist approach in game development (Bado 2022), the experiences and educational needs of the target group will be integrated. Currently, the narrative-based serious game is in its development phase, where content, materials and learning objectives are defined. The game is designed to provide low-threshold learning access and to be carried out easily within the company independently with the assistance of a moderator. Thus, it also contains elements of pen and paper games that make use of the intuition and improvisation of players to promote the level of creativity in interaction and also address emotional aspects.

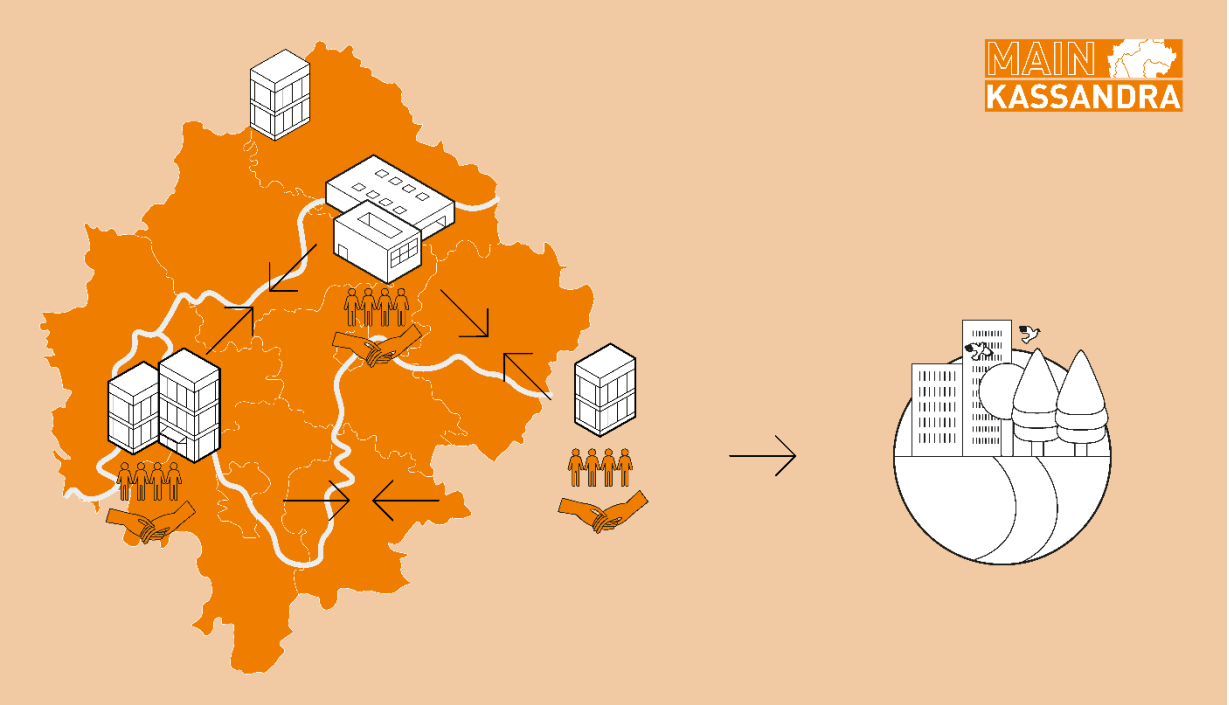


Figure 2: First game concept for 'MainKassandra', where players work collaboratively and competitively in a company in a region affected by climate change and have to make decisions and react to unexpected occurrences, own illustration

Conceptually, 'MainKassandra' is about game players developing a sustainable corporate strategy based on assigned functions, competencies and companies over several rounds and identifying their own affectedness, opportunities and risks with regard to climate change, see Figure 3. The game is played in teams facing each other in a competitive game situation, so that the different decision-making paths of the teams and their evaluation are analyzed in iterative lessons-learned phases. There are different organizational pre-conditions within the game that affect the decision-making regarding climate mitigation and adaptation strategies. Climatic events (e.g. heavy rainfall, floods) and developments in further dimensions (e.g. legal regulations, local conditions, warming, acceptability) and increasing knowledge influence subsequent decisions and strategy development. Assessment indicators, e.g. corporate image, profitability, are used to represent the effects of the decisions. 'MainKassandra' Is about making decisions and acting according to the assigned functions in the team in such a way that the fictitious company proves resilient to the specific event and future climate risk issues in order to avoid economic damage.

Regarding the game development, the empirically collected climate-relevant measures are to be cataloged in order to serve as a decision-making guideline or inspiration for the players of the game. One challenge in general is to develop a low-threshold game that the companies can carry out independently during workshops with their executives, with no required training for the moderator and with no risk of having the target group feel bored or deterred, for example, by complex game logics. Consequently, a low use of resources is required, along an analog and digital implementation using game materials printed out or used digitally and complemented by digital pinboards, e.g., Padlet. To ensure effective leaning, it is important to activate the players, to exchange ideas and to foster both their enthusiasm and motivation. Especially the question of resources and the question of the game logic or the score schemes regarding measures are currently in the focus of attention.

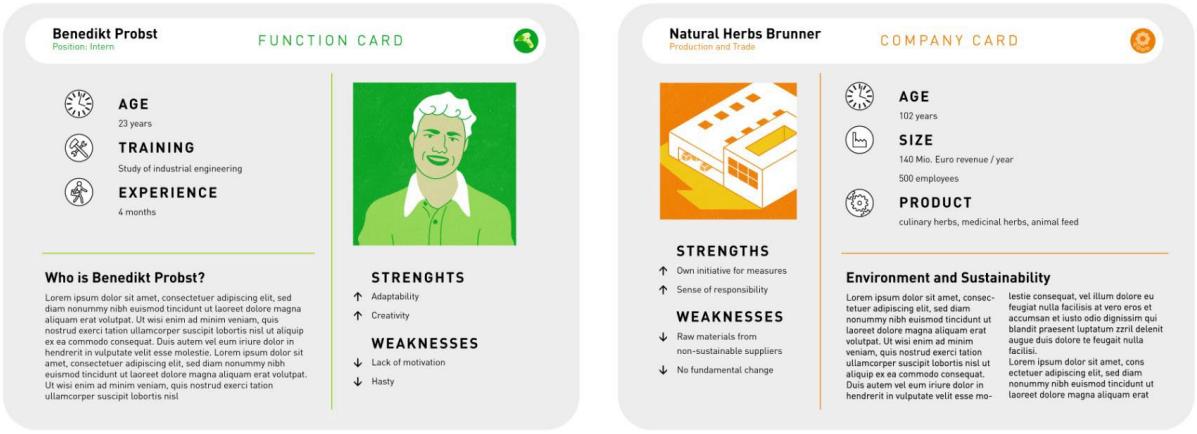


Figure 3: Design of game cards on fictitious functions and their competencies or character traits and the company cards as counterparts, own illustration.

As illustrated by economic conditions in particular and the certain unpredictability of climatic trends and extreme weather events, addressing climate change will be mandatory for all actors in economic and ecological systems in future. It is also important to note that actors who address their preconditions, opportunities and risks early and who have structures and capacities that facilitate their strategic learning processes will increase their climate resilience as well as reduce their vulnerability to uncertainties.

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Pedagogical Foundation to Promote Students' Engagement and Creativity While Co-creating a Music Learning Game

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Abstract: Learning-game co-creation is a pedagogical activity where learners draw on their knowledge of a specific topic to collaboratively create a learning game that peers can later use to gain a new understanding of a topic (Kafai & Burke, 2015; Kangas, 2010). Indeed, this approach offers important learning opportunities, as students call upon their acquired knowledge to create the different components of their game (e.g., rules, objective, dynamics, elements), all while also calling upon their creativity and encouraging their engagement with the activity. Studies exploring game creation as a learning activity have allowed us to identify and understand the common phases of this process. However, it is less clear to determine which are pedagogical principles the teacher should consider when implementing this approach into their own "teaching reality." In this paper, we present a pedagogical experience based on co-creating a music learning game with seven young musicians (age: 10–14). More specifically, our paper presents the educational, operational, and conceptual models that enabled us to establish a robust pedagogical foundation upon which we built this learning activity that, to our knowledge, had never been explored in our field (music education). Therefore, we will explain how we used each model to a) structure the set of activities that enabled the participants to create their own music learning game, b) guide the researcher's pedagogy act to co-create a music learning game with the students, and c) understand the participants' creative response towards this learning activity.

Keywords: Creative pedagogy, Game co-creation, Music Education, Creativity, Engagement

1. Introduction

The domain of music pedagogy shows a growing interest in diversifying the existing teaching methods to integrate pedagogical activities that better adapt to the interests of the new generations (Upitis et al., 2015) and further develop their creativity (Burnard, 2017). For example, music teachers are integrating into their lessons various digital tools that students use in their daily lives (e.g., mobile phones or tablets) for various purposes (e.g., explore different interpretations of a musical piece, share pedagogical resources, follow-up with practice, etc.) (Upitis & Abrami, 2017). As well, music teachers are starting to integrate more creative pedagogy approaches (Burnard, 2017; Lin, 2011), notably to foster students' creativity through creative musical activities such as composing (e.g., Burnard, Boyack & Howell, 2017), improvising (e.g., Burnard & Boyack, 2017), or creating invented partitions (e.g., Erman, 2011). Despite this growing interest, many pedagogical workshops and training offered for music teachers still focus on improving instrumental technique or performance, paying less attention to strategies that could allow them to develop a more creative pedagogy (Crow, 2008; Uszler, 1996). Furthermore, while some creative approaches are already documented in music (Burnard, 2017), they provide very few specifications about the pedagogical principles or foundations necessary to successfully implement this type of approach.

Given the above, there is an urgent need to explore scientifically more creative pedagogical approaches that could adapt to the domain of music pedagogy. Also, it is necessary to provide a clear description of the pedagogical principles and strategies necessary to implement such a creative pedagogy approach effectively. Our doctoral study aimed to step in that direction by documenting and analyzing a pedagogical experience based on co-creating a music learning game with seven young students (10–14 years old). We were interested in exploring this approach as, according to the literature, game creation fosters students' creativity by establishing creative links between the subject studied and the creation of different game elements (ex.: the story, the characters, the game world, etc.) (Kangas, 2010; Navarrete, 2013, Schanzer, Kirshnamurthi & Fisler, 2018). Moreover, according to a pilot project conducted by Marin-Jimenez (2018), this approach seems to adapt to the context of teaching and learning music.

1.1 Co-creation of learning games

Game co-creation as a learning activity refers to a process where students call upon their previous knowledge to create, in collaboration with other students, a learning game that aims to be played by their peers or less advanced students (Kafai & Burke, 2015; Kangas, 2010). During this process, learners determine their game's

pedagogical (e.g., learning goals and learning mechanics) and playful aspects (e.g., game objective, rules, elements, etc.).

According to the literature, this process seems to positively affect students' creativity and engagement. As for creativity, it invites students to use their knowledge in a creative way (Baytak & Land, 2010). For example, creating new characters (e.g., Navarrete, 2013; Schanzer, Kirshnamurthi & Fisler, 2018) or game worlds (e.g., Kangas, 2010) based on the learning concepts they chose to integrate into the game. As well, game co-creation calls upon students' critical thinking and problem-solving skills, as they must choose, among all the ideas shared by the group, those that work the best for their game (Vidoni & André, 2017). Finally, by creating a learning game with their peers, students develop social skills important for any collaborative creative process, such as openness to new and different ideas (Fernandez-Rio & Morales-Salles, 2020), negotiation, and leadership (Vidoni & André, 2017).

Regarding engagement, game co-creation seems to foster different factors that support student engagement. For example, the literature suggests that students appreciate game co-creation activities, as they often represent a positive experience (i.e., fun, amusing, interesting) for them (Fernandez-Rio & Morales-Salles, 2020; Schanzer, Krishnamurthi & Fisler, 2018; Vidoni & André, 2017). Moreover, co-creating games enable the acquisition of "extra" knowledge perceived as valuable by the students (Reynolds & Harel Caperton, 2011). For example, students might have to learn how to do basic coding (e.g., Scratch) or how to use design software (e.g., Canva) to create elements for their digital or non-digital game. Indeed, this knowledge also develops their feeling of competence, enabling them to successfully create their game (Reynolds & Harel Caperton, 2011) and feeling proud about the outcomes (Schanzer, Krishnamurthi & Fisler, 2018). Finally, game creation fosters students' sense of autonomy, as they can make decisions and establish their strategies during the creation process (Vos, Van der Meijden & Denessen, 2011).

1.1.1 The implications of pedagogy on the development of students' creativity and engagement

The pedagogical act (Shulman, 1987) implemented by the teacher plays a crucial role in the development of learners' creativity and engagement (Beghetto & Kaufman, 2010), which is one of the main goals of creative approaches such as co-creating learning games (Kangas, 2010). According to the literature, some of the pedagogical factors that promote students' creativity while learning are:

1. Integrating innovative and engaging teaching strategies (e.g., Kaplan, 2019).
2. Designing a learning environment that stimulates creativity (e.g., Cochrane & Antonczak, 2015; Richardson & Mishra, 2018).
3. Adopting an open and flexible attitude towards students' creative expression (e.g., Chen, 2008; Cremin, Barnes & Scoffham, 2009; Tran et al., 2017).

However, the strategies and intentional design of learning environments to support creativity in children have been very few explored in the educational research literature (Beghetto & Kaufman, 2014). As studies have reported, teachers interested in adopting more creative and innovative approaches, notably game co-creation, hesitate to do so because they lack the pedagogical strategies to do it (Kangas, 2010). In other words, they need reference models to do this adequately and securely.

The following paragraphs present the theoretical and conceptual models that guided our study to create a robust pedagogical foundation to co-create music learning games with seven young music students. More precisely, we will describe how we used these models to structure the activities that led participants to create their music learning game; guide the researcher's pedagogy act while co-creating games with the participants; and understand the participants' creative response towards this learning activity.

2. Participants and context of the experiment

Seven young students (six boys and one girl, aged 10–14) who were learning different instruments (e.g., guitar, piano, violin, cello, saxophone, and flute) in an out-of-school context[1] participated in a 10-week pedagogical experience animated by the researcher (Marin-Jimenez). Each week, participants worked in collaboration towards creating an analogic music learning game about music theory. The sessions took place once a week (on

[1] Students that learn a music instrument in an out-of-school context in the north-western part of the globe (i.e., United States and Canada), usually attend to their lesson once a week, after school hours, in a private setting, such as: the student's home, the teacher's home or music studio, online, or at a private music school.

Saturdays) for three hours at the LaRFADI (Laboratoire de recherche en formation auditive et didactique instrumentale), a research laboratory located at the Faculty of Music at Laval University in Quebec City, Canada. Every session was recorded (video and audio) for further analysis. The laboratory is equipped with different resources, which are useful to achieve the game creation process. For example, digital tools (e.g., iPads, laptops, and a projector), as well as several music instruments (e.g., a grand piano, percussions, guitars, boomwhackers) and movable furniture (e.g., tables and chairs) allowed the participants to accomplish different tasks in collaboration or individually as needed.

3. Models that built the pedagogical foundation to co-create music learning games

3.1 To structure the game co-creation activities: Creative and Playful Learning Model (Kangas, 2010)

The Creative and Playful Learning (CPL) model of Kangas (2010) proposes four developmental phases (orientation, creation, gameplay, and elaboration) to co-create a learning game with students within a playful learning environment:

1. Orientation: this phase aims to familiarize students with the learning theme and later integrate it into their game. To do so, students can do autonomous research on the subject, or the teacher can give a brief presentation on this topic.
2. Creation: based on the concepts studied in the previous phase, students create, in collaboration, the first prototype version of their game (i.e., they develop the game's components such as rules, aesthetics, story, world, theme, etc.).
3. Gameplay: during this phase, students test, analyze, improve, and retest their game as needed until the final version of their game is achieved.
4. Elaboration: this phase aims to revise the knowledge that students have gained during the process. To do so, the teacher asks key questions to students about what they learned and their overall experience in creating their game.

In the context of this doctoral project, these four phases allowed the researcher to structure a set of activities that would adequately guide the participants towards co-creating their own music learning game. As a result, the participants succeeded in creating "The war of six clans", a music trivia game where the learning objective was to reinforce the learning of precise musical concepts such as rhythm, note values, scales, and instruments (figure 1).

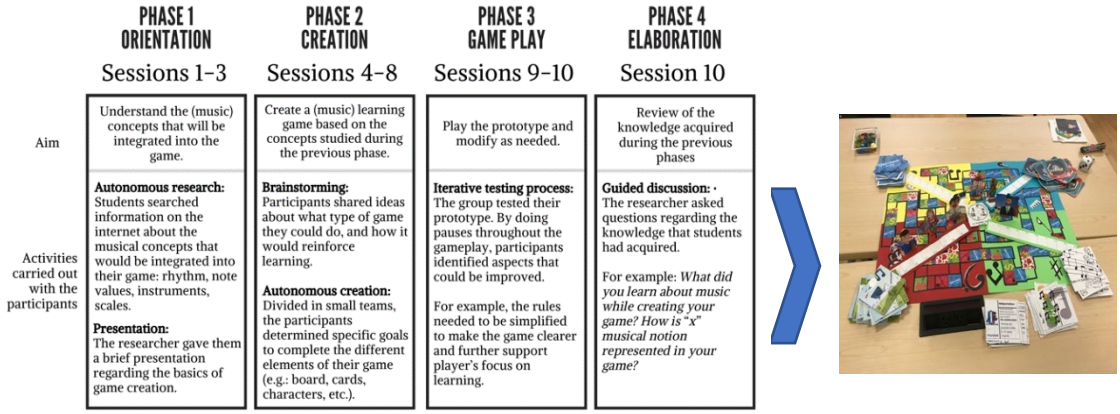


Figure 1: Activities based on the CPL model (Kangas, 2010) that allowed the participants to finish their music learning game "The war of six clans"

3.2 To guide and evaluate the pedagogical act of the researcher: creative pedagogy (Lin, 2011)

As one of the intended goals of co-creating games with students is to nurture and develop their creativity and engagement, the researcher referred to the model of Creative Pedagogy of Lin (2011) to ensure that her actions and choices were geared towards that objective.

The Creative Pedagogy model (Lin, 2011; 2014) illustrates the meaningful relationship between the pedagogical act and the learner's creative potential development. More precisely, the model proposes that students' creative

potential can be developed through the interconnection of three essential components: *creative teaching*, *teaching for creativity*, and *creative learning* (figure 2).

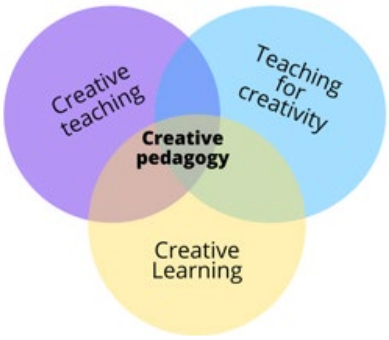


Figure 2: The three components of Creative pedagogy, as presented by Lin (2014)

3.2.1 Creative teaching

The first component, *creative teaching*, refers to the teachers' actions that foster students' creativity and encourage their autonomy (Lin, 2011). For example, activities that: a) call upon students' imagination to generate and develop new ideas (e.g., Cremin, Burnard & Craft, 2006), b) create links between the subject studied and their interests and experiences (e.g., Hagay et Baram-Tsabari, 2015; Rankin et Brown, 2016), and c) promote social interaction (e.g., share ideas, give and receive feedback from peers) as well as individual autonomy (e.g., complete creative tasks individually, which will contribute to the group's goal) (Cremin, 2009; Toivanen, Halkilahti et Ruismäki, 2013).

In the context of this study, these *creative teaching* principles led the researcher to prioritize activities that would encourage students' creative expression and autonomy while creating their game. For example, rather than presenting the musical concepts through a presentation, the researcher preferred to have the participants research the music concepts that they would integrate into their game autonomously (i.e., by searching the concepts on the internet individually or in teams). Indeed, she considered that this activity would further stimulate participants' curiosity and autonomy, as they could formulate different questions about the subject and create research strategies to find information.

3.2.2 Teaching for creativity

The second component, *teaching for creativity*, refers to the teacher's efforts and attitudes to create a positive learning atmosphere that supports students' creative development (Lin, 2011). To do so, *teaching for creativity* encourages teachers to adopt an open and welcoming attitude towards students' different ideas, so they can highlight their originality and help them develop their initial ideas into concrete realizations (Richardson & Mishra, 2018). This component also invites teachers to take a step back to become more aware of learners' creative (or less creative) responses and provide support accordingly (Barbot, Besançon, & Lubart, 2015). Finally, *teaching for creativity* also refers to the teacher's efforts to accommodate the physical (e.g., Kangas, 2010) or virtual (e.g., Schiavio, Biasutti & Antonini Philippe, 2021) learning environment to encourage learners' creative expression (Lin, 2011). For example, the disposition of digital (e.g., iPads, computers) or non-digital (e.g., papers, colours, cardboard, etc.) resources can support the visual representation of students' ideas (Cress & Holm, 2016; Richardson & Mishra, 2018). Also, the furniture's placement within the learning space (e.g., placing the tables in a circle rather than inline) could further encourage students to collaborate with others (Gundersen, 2019; Starkey et al., 2021).

In the context of our project, the principles of *teaching for creativity* led the researcher to adopt an attentive and supportive attitude towards students' creative responses. For example, when participants were creating the game's characters (creation phase), she identified that some participants expressed their character ideas best when they drew them by hand. In contrast, others were more comfortable using design software like Canva. In response to this observation, the researcher provided all the necessary materials (e.g., pencils, erasers, coloured pencils, and paper, as well as computers and iPads) to support these two different ways of expressing creativity within the group. Also, when the researcher noticed one participant was following a drawing tutorial on YouTube to improve his drawing skills (figure 3), she provided all the material he needed to practice (e.g., paper, pencils,

colours, etc.), and she also encouraged his effort and provided constructive feedback needed until he completed his design.



Figure 3: Strategic deployment of resources (e.g.: coloured pens, papers) within the learning space to support participants' creative intention (e.g.: design a character by hand)

Also, when the researcher noticed that participants wanted to share an idea with the group, she invited them to use the projector to present their idea and stimulate group discussion and feedback (figure 4).

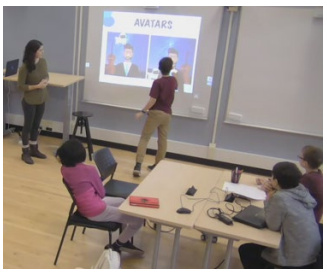


Figure 4: Strategic disposition of resources (e.g.: projector) within the learning space to support participants' creative expression (i.e., present his character ideas to the group)

Finally, these principles also guided the researcher's choices regarding the set-up of the (physical) learning space. For example, throughout the creation phase, she formed "collaborative working stations" with the laboratory's tables (figure 5). According to the researcher's observations, this furniture set-up further encouraged participants to share ideas, collaborate, and discuss with each other.



Figure 5: Strategic furniture placement within the learning space to promote participants' creative expression and collaboration

Thus, *creative teaching* and *teaching for creativity* interconnect to nurture learners' creativity. However, creative pedagogy is only effective once these two components correspond to the students' *creative learning* experience, which is the last component of the creative pedagogy model (Lin, 2011).

3.2.3 Creative learning

The third component, *creative learning,* refers to the process where learners construct new learning from the application of their creative skills (Beghetto, 2016) or habits which, according to Lucas (2016), can regroup into five different creative dimensions: 1) being inquisitive (i.e., constantly ask questions to understand a topic better) (e.g., Chappell et al., 2008), 2) being imaginative (i.e., generate new ideas and explore various possibilities to solve a problem) (e.g., Pinter, 2017), 3) being disciplined (i.e., use critical thinking to make important decisions, establish strategies, and solve problems) (e.g., Gundersen, 2019), 4) being collaborative (i.e., collaborate with others to discuss, negotiate, or accomplish common goals) (e.g., Kangas, 2010) and 5) being

persistent (i.e., being perseverant when encountering challenges or difficulties during the creative process) (Lucas, 2016). However, *creative learning* also manifests through different factors of learner engagement (O'Neill, 2013). For example, when students learn actively by being in control of their work (e.g., by making decisions regarding the consulted sources of information, the sequence of activities to be completed, or the pace at which they will achieve them) (Cremin, Burnard & Craft, 2006). Also, when students manifest a certain degree of autonomy to make their own choices about which tools, resources, and strategies they will use to complete their tasks more efficiently (Schmenk, 2005).

In this study, the researcher referred to the principles of *creative learning* to better understand the participants' creative responses while co-creating music learning games. Indeed, this information allowed her to evaluate if her *creative teaching* and *teaching for creativity* strategies were effective.

Based on Lucas's (2016) model of 5 dimensions of creativity, the researcher carried out a deductive thematic analysis (Rossman & Rallis, 2016) of the recorded sessions to identify specific moments which seemed to indicate a creative learning response from the participants. One of these examples was identified during the orientation phase when participants were autonomously researching information about the musical concepts they would incorporate into their game. Indeed, this autonomy-supportive activity (*creative teaching* strategy) seemed to encourage several creative dimensions (Lucas, 2016).

First, participants were "being inquisitive" as they constantly asked concrete questions (to the researcher or their peers) about the musical concepts they were researching, either to solve doubts or to know more about a topic that interested them. Also, this activity fostered participants' creative dimension of "being disciplined" as they set clear and specific research goals and established strategies to complete the task on time. For example, some participants decided to work in pairs, so one could search for information on the internet while the other took note of significant findings. Indeed, these self-regulation strategies indicate a certain degree of engagement, as they refer to an active learning experience (an important factor of engagement, according to O'Neill, 2013). Moreover, participants mobilized their creative dimension of "being collaborative" as they helped each other to resolve doubts that arose during their research. For example, as participants had to research information about different musical instruments, we observed that a violinist asked a pianist: "How many keys does a Grand Piano have?" and a pianist asked a guitarist: "How many strings does a guitar has?". Indeed, this collaborative response was also fostered by the researcher's strategic placement of the furniture (*teaching for creativity* strategy), as she set up the tables facing each other to incite exchange and discussion among the participants. Finally, the researcher's attentive attitude (also *teaching for creativity* strategy) seemed to foster participants' engagement, notably through specific engagement factors (O'Neill, 2013) such as "perceived challenge", "perceived support", and "competence". Indeed, this attitude helped her to identify and provide support to participants having more difficulties in understanding certain musical concepts that were being studied, notably scales. This support was important, as this experience could frustrate participants, affecting their engagement level and impeding their creative expression during the task. Consequently, these participants perceived the activity (i.e., autonomous research of complex musical concepts such as scales) as attainable because the researcher's support allowed them to overcome the difficulties and persevere until they accomplished the task. Also, by respecting the other participants' autonomy (i.e., those who understood scales), the researcher fostered their feeling of competence, as they could complete the task by themselves and use their knowledge to help others.

Figure 6 below resumes this example by presenting the interconnection points between the three components of Lin's creative pedagogy model (2011) and several aspects of each component observed while completing the activity of autonomous research (orientation phase). Then, the picture presented in figure 7 highlights some of the numbered aspects in figure 6.

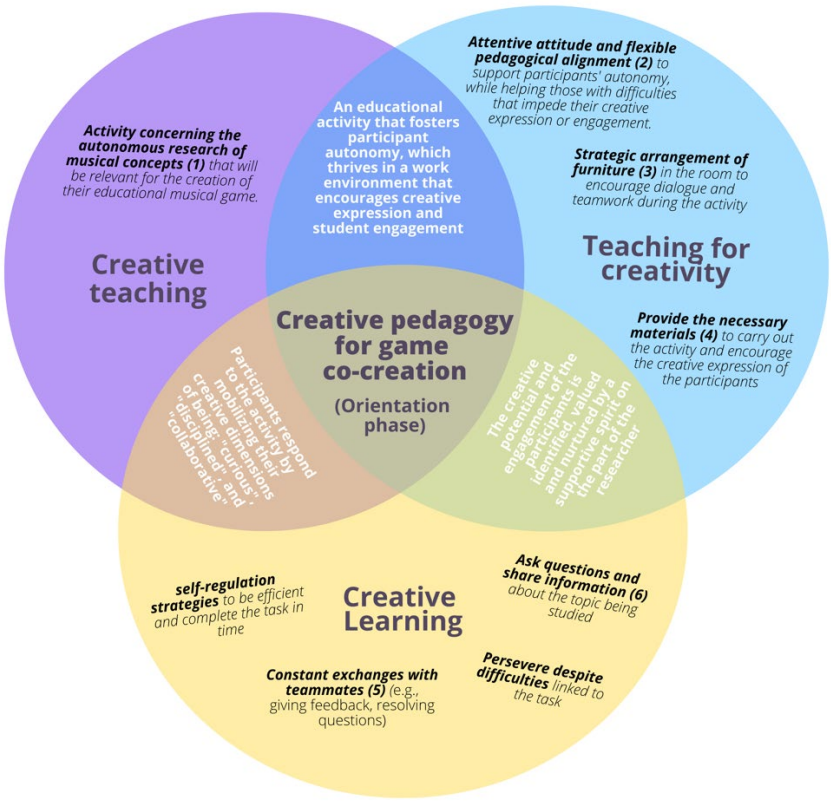


Figure 6: Interconnection of the three components of creative pedagogy (Lin, 2011) while co-creating games with the participants during the orientation phase



Figure 7: Observed interconnection of the three components of creative pedagogy during the orientation phase

4. Conclusion

This paper presented the theoretical and conceptual models necessary to establish a robust pedagogical foundation to co-create a music learning game with seven young music students. First, the Creative and Playful model of Kangas (2010) was used to create a four-phase structure of activities that enabled the participants to create an original music learning game successfully. Then, as one of the main goals of this approach was to develop students' creativity, the researcher referred to Lin's three components of the Creative Pedagogy model (2011) to guide her pedagogy approach. First, the *creative teaching* component led the researcher to prioritize activities that supported participants' autonomy (e.g., autonomous research of information) while co-creating their game. Then, the principles regarding *teaching for creativity* allowed the researcher to create a positive learning environment that promoted participants' creativity. To do so, she adopted an attentive attitude towards participants' creative response to encourage their creative strengths and provide support when encountering challenges. Then, she encouraged participants' creative expression by strategically using the available resources within the learning space. For example, she offered paper and coloured pens so participants could visually represent their ideas (e.g., sketch game characters). Also, she allowed them to use the projector

to present their ideas and receive feedback from their peers. Finally, the principles of *creative learning* allowed the researcher to understand better participants' creative responses to this type of approach. For example, during the orientation phase, participants mobilized different creative dimensions (Lucas, 2016), such as: "being inquisitive" (i.e., by asking concrete questions to understand the musical concepts they would eventually integrate into their game); "being collaborative" (i.e., by helping their peers to solve their doubts and provide feedback about their creations), and "being disciplined" (i.e., by establishing their strategies to complete their tasks on time).

Finally, this phase also fostered participants' engagement through different factors (O'Neill, 2013), such as autonomy (i.e., as they were in control of the decisions regarding their game) and competence (i.e., as they were able to complete most of the tasks by themselves). These outcomes, which are a portion of Marin-Jimenez's doctoral study, respond to the need identified by Kangas (2010) for providing more resources that would guide teachers' "pedagogical thinking" to implement innovative and creative approaches such as co-creating learning games, in our case, within a music teaching context.

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NanoDoc: Designing an Adaptive Serious Game for Programming with Working Examples Support

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Abstract: There is an increased interest in serious games about programming, particularly for younger ages. The ability to evoke motivation and retain engagement leads to better learning efficiency and a positive educational impact. Serious games usually include support systems to assist novice users. In recent years there have been attempts to enhance support with intelligent tutoring systems. These systems adapt and provide personalized learning by analyzing user behaviour. Although this is a positive evolution, support still remains in the form of hints, images and videos. The paper describes an alternative adaptive method for support with working examples. An expert solution to a similar problem is displayed to the students allowing them to address the problem and start the solving process by analogy. Our previous research showed that working examples can reduce cognitive load during problem-solving and increase the student's educational results in comparison to traditional techniques. This paper presents the design of NanoDoc, a serious game for teaching the programming concepts of sequence and iteration to elementary school students. It features adaptive support with editable and executable working examples. Each example can be examined, edited and executed freely by the user until the required knowledge level is sufficient to solve the similar problem at hand. The adaptation method is based on a Fuzzy Logic algorithm and the dynamic modelling of user knowledge level. The paper also provides some preliminary results on student usage in the classroom and a questionnaire about the game experience. Plans for future research include investigating if adaptive support with working examples can reduce cognitive load even further and how learning is affected.

Keywords: Serious games, adaptive support, programming, worked examples

1. Introduction

Computer programming has become an important skill in the 21st century and schools around the world are including it in their curriculum. Although it might differ from country to country, teaching programming commonly begins in the early grades of elementary school. Serious Games (SGs) are an essential tool for that task, particularly to novice students (Miljanovic & Bradbury, 2018). The learning mechanic is embedded with gameplay and that aspect can result in enhanced learning through motivation and active engagement (Laine & Lindberg, 2020). SGs promote student-centred learning and utilize self-teaching tools with support systems. Those systems usually include text, images and video to deliver educational content to students along with gameplay. The learning material can be received as generic as it was created for the average student and it was not fashioned for the specific needs of a user. To overcome this problem, Intelligent Tutoring Systems (ITS) have emerged to adapt the support content and provide personalized learning. ITS can act as a private tutor supervising the learning process and offering specific support when needed.

This paper presents the SG NanoDoc for teaching programming to novice users with adaptive support. The method of chosen support is Worked Examples (WEs), an approach that results in high learning efficiency and consistency according to relevant studies (McLaren et al., 2014). WEs are used in traditional teaching too, where the instructor presents a problem to the students and then guides them step by step to the solution. It is a particularly effective procedure applied to novices when they learn to solve complex problems (Sweller, 2006). Inexperienced programmers have difficulties when they encounter a new problem. They can not classify it according to the underlying principle that leads to a solution. This information is retained only by encountering several similar problems and creating a mental representation of the related programming structure that solves the category. WEs provide that information by helping students to create mental models for specific types of problems. The increased efficiency of this support method derives from the fact that by using it, students have a reduced cognitive load (Sweller, 2006). The cognitive load is the mental effort produced during learning and when it is high, the thought processes interfere. Consequently, it is essential to keep the cognitive load to a minimum, enabling students to absorb more knowledge.

In this paper, we examine a method of adaptive WE implementation in a SG about programming. NanoDoc has integrated WEs into the game, allowing players to passively study solutions to programming puzzles. We explore

the findings of a pilot use case of NanoDoc in a group of elementary school students. The results will further refine the game so it can be utilized in future studies. The next section presents a review of the related work in the field. Next, we introduce the game and its mechanics, followed by a description of the adaptive support methodology. Then, the results of the evaluation questionnaire about the game are presented. Lastly, the results are discussed and the final conclusions are addressed.

2. Related work

Although a few SGs implement adaptive support in teaching programming and prior work is scarce (Hooshyar, Malva, et al., 2021), it has been shown that it is most effective when applied. There is a diversity in the proposed methods such as Bayesian networks, Fuzzy Logic and Deep Learning. Moreover, despite the fact that the main objective is to enhance student learning, there is no common aspect of adaptation or method of presentation.

The ENGAGE game (Min et al., 2014) examines adaptive task selection and adaptive hint generation utilizing dynamic Bayesian networks to teach computer science principles to middle school students. The block-based puzzle game BOTS (Hicks et al., 2015) provides feedback in the form of personalized hints by analyzing the user output and the world state after each program execution. The HTML escape (Papadimitriou & Virvou, 2017) is an adventure game that uses Fuzzy logic to alter dynamically some of its assets like rooms, items and characters according to the player's knowledge level. AutoThinking (Hooshyar et al., 2021) employs a Bayesian network to adapt both gameplay and feedback by adjusting textual and graphical cues and adapting the difficulty of gameplay to the player's ability. In Minerva (Lindberg & Laine, 2018), a game about teaching programming to elementary school students, the content adapts to student learning styles in an attempt to increase motivation.

3. The Game

NanoDoc is a serious game designed to introduce students to the concepts of sequence and iteration in programming. It has been developed in the Unity game engine (*Unity Real-Time Development Platform | 3D, 2D VR & AR Engine*, n.d.) and deployed as a WebGL application to run on the Web. All the 3D models, textures and animations used in the game were obtained from a microgame template distributed freely from Unity Technologies. Special care has been taken to ensure that NanoDoc can run efficiently on computers with low specifications in terms of CPU and GPU. The intent was to be used in school computer labs that often are under-equipped, so techniques like lightmaps, mesh merging and occlusion culling were implemented. The game can be classified as a first-person shooter where the action and navigation in the three-dimensional space are perceived through the player's eyes (Figure 1). Students assume the role of a doctor who has been miniaturized inside a sick creature. The objective is to save the patient by curing it of the viruses while avoiding all the dangers lurking inside. A Non-Player Character (NPC) in the form of a red cell, operates as a companion to the player offering assistance and guidance.

An effort has been made to keep the quality of the game on a similar level to modern entertaining software the students use to play in their free time. The graphics are stylized and vividly colored, the hints are animated and the environment is decorated with a variety of items. The moving traps, enemies and walls, combined with music and sounds create a lively world and assist in player immersion. The mouse and keyboard inputs follow the standard consensus of the first-person shooter genre in order to minimize possible navigation control problems. We also tried to create interesting puzzles and maintain a smooth learning curve. Additionally, the adaptive support provides users WEs instead of textual instructions, decreasing cognitive load. Finally, the programming environment is block-based and built with the same functionality the students are familiar with from other educational software like Scratch.



Figure 1: The first-person shooter perspective of the game

3.1 Game mechanics

The game is a microcosm maze consisting of rooms connected with corridors and decorated with elements related to internal physiology. Several rooms include obstacles and traps whilst some of them are dead-ends. Additionally, enemies drift through the corridors, equipped with the basic behaviours of wandering, chasing and fighting. There are three types of enemies differentiated by their hit points and can be eliminated with a unique gun that players are equipped with. A handful of rooms are blocked with a substance which can only be unlocked with a corresponding protein key (Figure 2). The key is usually located in a nearby room of the sealed door and players have to solve a programming puzzle to acquire it. Each puzzle relates to a programming concept with a gradual increase in complexity as the player progresses through a total of twelve puzzles.



Figure 2: The protein key

During the programming phase (Figure 3), the game switches to a hybrid 2D/3D mode. The puzzle is depicted as a 3D grid containing a key and an avatar. In order to solve the puzzle, the player has to create a program that controls the avatar's movement in the grid and be placed in front of the key to pick it up. Some puzzles include obstacles to prevent direct access to keys, so alternative routes must be discovered. The solution algorithm is constructed in a 2D block-based programming environment. Every command or action is represented with a block that can be connected with others and form a program. The visual interface programming experience is equivalent to the Scratch educational software (Scratch - About, n.d.). In particular, blocks are coloured based on their structure collection and can be handled intuitively with drag and drop actions.



Figure 3: The programming phase

3.2 Support design

The game provides assistance during gameplay and adaptive support in programming. The NPC communicates with text messages and informs players about upcoming dangers or instructs them on game controls and mechanics. Those messages are animated and placed in the lower centre of the screen in order to grab the player's attention. In addition, flashing arrows in specific corridors and a mini-map are offered to assist with navigation in the maze. The adaptive instructional support is activated within the programming phase. The game creates a model of player knowledge level for the domains of sequence and iteration and updates it with every submitted solution. If an insufficiency of the required knowledge for the current puzzle is detected, the game presents players with a worked example of a compatible problem. The WE is editable and players can examine and execute it without restrictions until they conclude that the required knowledge was perceived (Figure 4). Whenever the adaptive support is triggered for a puzzle, an associated animated button placed in the toolbar area is enabled. With this button, players can swap between their code/puzzle pair and the WE ones without restraints until they solve the puzzle.

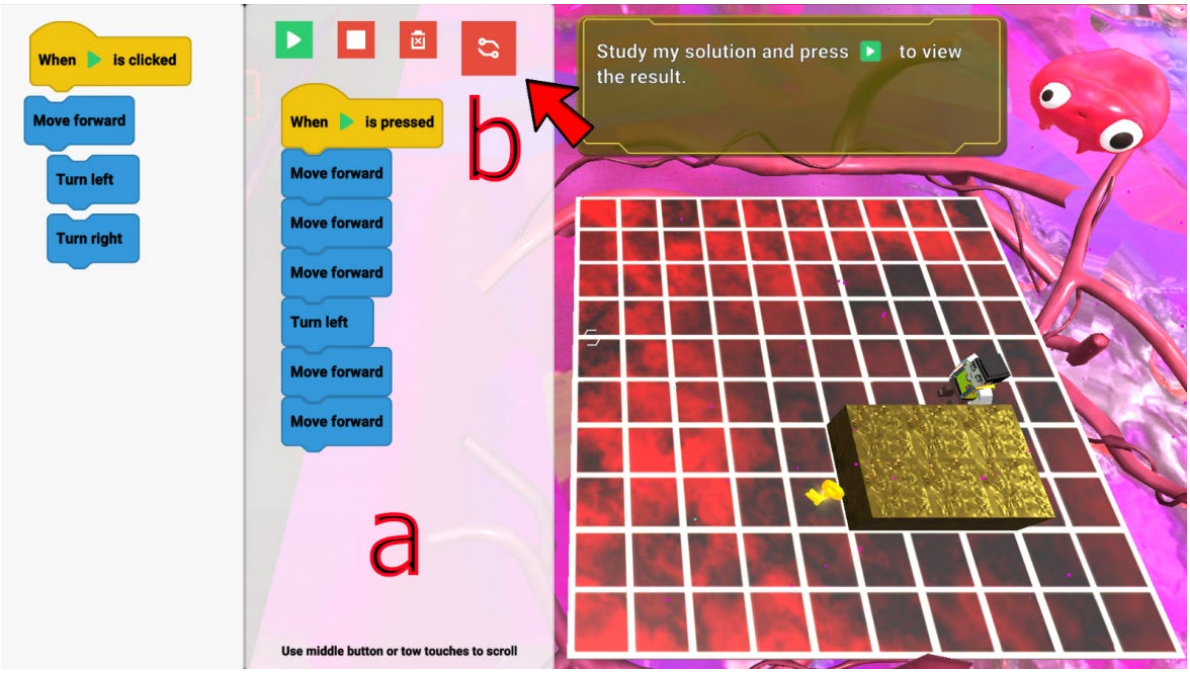


Figure 4: Support enabled (a) the WE (b) The hide WE button

4. Adaptive support

The adaptive support model extends a previous method from the education game FuzzEg (Papadimitriou et al., 2019) and applies Fuzzy logic to describe student knowledge level in a domain. The process can be defined by five steps:

1. Gather learning data from the player's submitted solution
2. Fuzzify the input values with membership functions
3. Apply a rule set to the fuzzy output
4. Map the fuzzy output into a crisp value
5. Adapt support according to the crisp values

Each time the player submits a puzzle solution, the game estimates a value that represents how optimized the solution is in terms of programming structures utilization. The equation (Equation 1) is based on a previous study (Toukiloglou & Xinogalos, 2022) and calculates learning efficiency by dividing the number of blocks of the optimal solution by the number of blocks of the solution committed by the student. The coefficient D defines the puzzle difficulty and varies according to game design. However, since every puzzle in this game uses the accumulated knowledge of the previous ones, the overall difficulty remains steady and D becomes a constant equal to 1.

$$Efficiency = \frac{Optimal\ Solution}{Student\ Solution} \times D$$

Equation 1: Calculation of learning efficiency

The formula transforms the data from a submitted solution into a positive decimal number with a maximum value of 1 which is the best possible result of a solved puzzle. The following step converts the efficiency score to fuzzy values using four membership functions (Papadimitriou et al., 2019) as depicted in Figure 5.

$$\mu Un(x) = \begin{cases} 1, & x < 45 \\ 1 - \frac{x-45}{5}, & 45 < x < 50 \\ 0, & x \geq 50 \end{cases}$$

$$\mu Uk(x) = \begin{cases} \frac{x-45}{5}, & 45 < x < 50 \\ 1, & 50 \leq x \leq 65 \\ 1 - \frac{x-65}{5}, & 65 < x < 70 \\ 0, & x \leq 45, x \geq 70 \end{cases}$$

$$\mu K(x) = \begin{cases} \frac{x-65}{5}, & 65 < x < 70 \\ 1, & 70 \leq x \leq 85 \\ 1 - \frac{x-85}{5}, & 85 < x < 90 \\ 0, & x \leq 65, x \geq 90 \end{cases}$$

$$\mu L(x) = \begin{cases} \frac{x-85}{5}, & 85 < x < 90 \\ 1, & 90 \leq x \leq 100 \\ 0, & x \leq 85 \end{cases}$$

Figure 5: Membership functions of knowledge fuzzy sets

Every puzzle of the game is associated with a specific learning domain, so the fuzzy output describes the knowledge level of the student in that domain. The knowledge level is described as a quadruplet (μUn, μUK, μK, μL) of the following fuzzy sets (Papadimitriou et al., 2019):

1. Unknown (Un): The domain concept is unknown to the player. Efficiency score is from 0.0 to 0.5
2. Unsatisfactorily Known (Uk): Player has some knowledge of the concept. Efficiency score is from 0.45 to 0.7
3. Known (K): Player knows the concept sufficiently. Efficiency score is from 0.65 to 0.9
4. Learned (L): Player knows the concept completely. Efficiency score is from 0.85 to 1.0

The fuzzy set definitions enforce certain restrictions for each quadruplet. The value of each component is ranging between 0 and 1 and the total sum of all the components is always equal to 1. Moreover, the values are adjoined since it is illogical to skip an intermediate set. Next, the defuzzify process converts the output data to a crisp value that defines the whole set. This value represents the knowledge level of the domain that is reviewed and is calculated using the Maximum-Membership method where the maximum value of the set is chosen. In the final step, a decision is made upon providing support to players according to a ruleset as shown in Table 1. This ruleset is based on the knowledge level for each domain which is constantly updated with every puzzle and the number of failed attempts of the current problem. Finally, support can also be triggered automatically by the

system when it detects inactivity for at least 120 seconds. This additional measure was set to address cases where students are stumped by the problem and can not continue without help.

Table 1: Support activation ruleset

Knowledge domain level	Failed attempts
Learned	4
Known	3
Unsatisfactorily Known, Unknown	2

5. Evaluation

To evaluate the state of the game regarding playability and support functionality, a questionnaire has been conducted in January of 2021 and lasted two weeks. A group of 85 (41 male, 44 female) elementary students of the same school, aged 10-12 volunteered to play the game. Most of the students (82%) had some programming experience with Scratch (*Scratch - About*, n.d.) and the rest were complete novices. The procedure was supervised by a teacher and took place in the school's computer lab. After a play session that lasted 45 minutes, students anonymously answered an online questionnaire that consisted of 3 sections with Likert scale responses. The first section is a single question querying the overall attitude of the student towards learning programming with serious games. The next two sections include several sub-questions and investigate student perception of the game and the difficulties they encounter. Lastly, a non-mandatory question was granted to comment openly about the game and it was answered by 31% of the students. The vast majority of comments were positive whereas some were requests for new features like a larger map, adding new weapons or a multiplayer option (Table 2). The rest of the results are shown as percentages in Figures 6 and frequencies in Figures 7 and 8.

Table 2: A sample of student comments (translated from Greek)

Player	Comment
Student 1	“The game had nice 3D graphics. I wanted to last longer and be more difficult”
Student 2	“The game was a lot of fun”
Student 3	“I wanted more weapon options and better enemies”
Student 4	“The game was nice and I want to replay it again”
Student 5	“The game was a blast. Add a multiplayer option please”
Student 6	“I enjoyed learning programming with this”

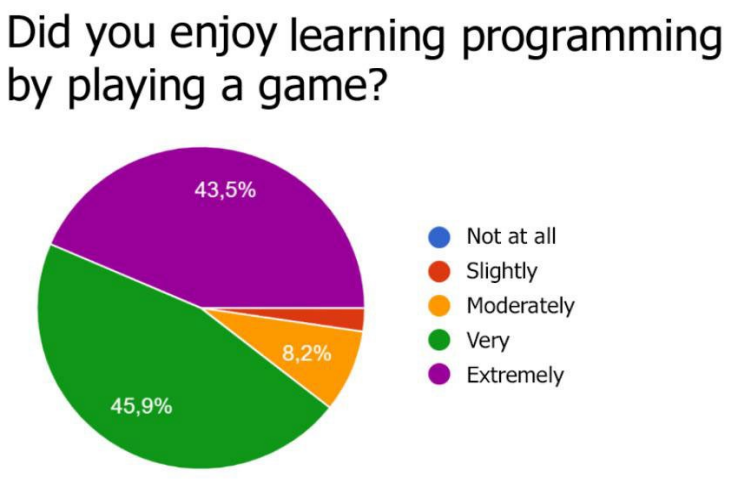


Figure 6: First section results (translated from Greek)

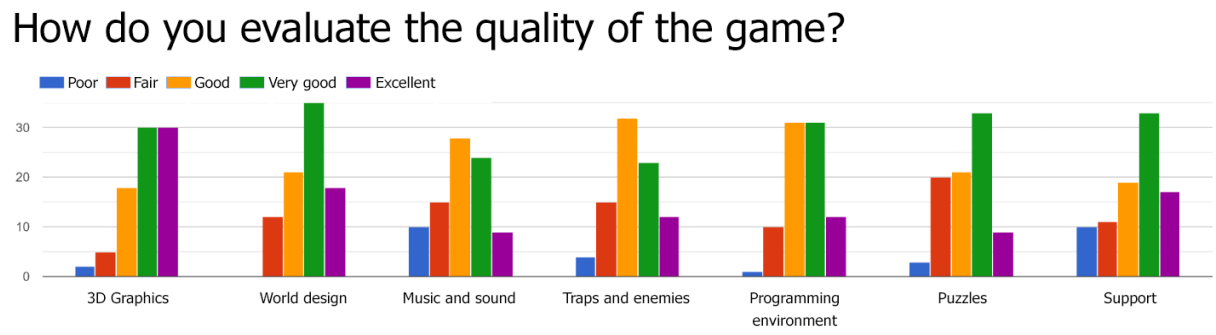


Figure 7: Quality results (translated from Greek)

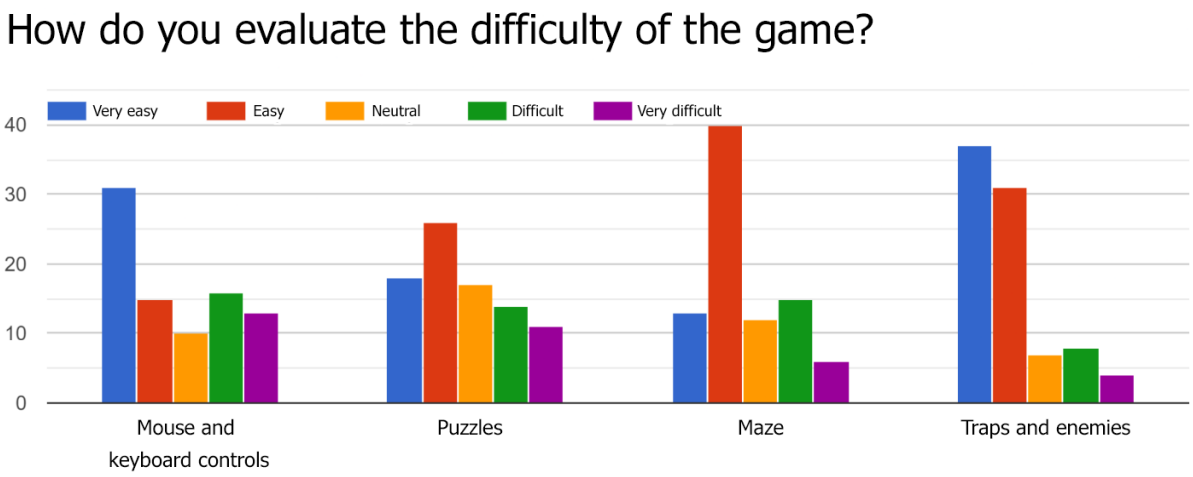


Figure 8: Difficulty results (translated from Greek)

6. Discussion

Although the number of participants in the questionnaire was small, the results were very encouraging. The answers of the first section concluded with an almost 90% positive opinion about learning programming with games. This finding agrees with previous studies about the motivation potential of serious games in education (Laine & Lindberg, 2020). The second section questioned the quality of various aspects of the game. The 3D visual representation of the world proved to be one of its strong assets and received good reviews both on graphics and world design. Sound and music however had a moderate impact, possibly due to external factors. During the game session in the computer lab, students were asked to lower the sound volume on their computers. This was decided to reduce the overall volume of the class and mitigate the disturbance of the thinking process during puzzle solving. However, this could have been avoided if students had received headphones. Any future designs that involve sound and music in serious games should take that factor into consideration.

The majority of the students had used a block-based programming environment in the past with Scratch. The resemblance with NanoDoc's programming environment proved to be beneficial as they reported no problems with the interface. It should be noted that half of the puzzles involved the iteration structure. Nonetheless, 85% of the students were only taught the sequence structure in the school while the rest were complete novices. Despite that, they liked the puzzles and found them relatively easy to solve. Also, the support method received very positive results. This concludes that the support method was effective in teaching the programming structures when needed and students manage to solve those puzzles without external help.

Enemies and traps in the game were relatively easy for the experienced players. The behaviours of enemies were simplistic and bumping into a trap would only cause a delay without other consequences. A better approach would have been to implement a Dynamic Difficulty Adjustment (DDA) (Min et al., 2014) system and alter the difficulty in compliance with the player's skill, maintaining the level of challenge. Nevertheless, dynamic difficulty was not in the scope of the study so an easy level of difficulty in obstacles was decided to help less experienced

players. This design decision caused a moderate response to the related question since it emerged that most of the students were experienced players in commercial games. Additionally, the answers in the third section about the difficulty evaluation in those areas of the game showed the same results.

Continuing with the third section of the questionnaire, students reported no problems with the game controls. The NPC companion provided useful tips about keyboard and mouse usage in the first parts of the game. Nonetheless, the game followed the typical mapping of functions found in similar games. This consistency allowed experienced players to immediately familiarize themselves with the controls and remove a potential side problem. The controls standardization is a common practice in commercial games and it is strongly advised to be followed as it was proven to be valid.

Despite the fact that the maze was difficult to navigate including close loops, dead-ends and split paths, students reported no problems. NanoDoc provided a mini-map and visual aid with flashing arrows pointing in the right direction at specific points in the maze. Players tend to dismiss text messages or alert boxes while navigating the world as they consider them to be annoying interruptions. Presenting the intended information as part of the game world confirmed that practice and will be followed in the future.

7. Conclusions

The serious game NanoDoc is presented with the intent of teaching programming to novice students. The game features an adaptive support system based on the Fuzzy logic model. The game creates a student model and provides support with working examples when it detects inefficiency in a knowledge domain. An evaluation of the game was conducted to a group of elementary students with a questionnaire. The results suggest an overall positive opinion about the game elements and mechanics. However the areas of difficulty and sound require refinement to meet student expectations. Enemies and obstacles should provide a greater challenge to keep player retention. It is also concluded that the adaptive algorithm operates as intended and students manage to solve problems without external help in unknown knowledge domains. These findings suggest that the problematic mentioned areas should be improved in the next version of the game.

In previous work (Toukiloglou & Xinogalos, 2022), we compared WEs with textual support and showed that WEs provide better learning efficiency due to reduced cognitive load. We plan to use NanoDoc in an empirical study that will investigate if the cognitive load can be reduced even further. An adaptive worked example support version of the game will be compared with a non-adaptive one in terms of learning efficiency. The research will be conducted on elementary students with limited previous experience in programming.

Acknowledgment

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Wealth Creation: Serious Game Development to Improve Financial Literacy for High School Students

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Abstract: Serious games simulate events in a virtual world to allow players to interact with the game's elements and other players within the game. In the field of health, transportation, economics, and finance, serious games were used as simulators in training. By playing a serious game, learners gained experience in making meaningful decisions through trial and error to solve problems in the virtual world. In this research article, the authors developed a board game to introduce concepts of Wealth Creation and studied the characteristics of board games suitable for developing high school students' financial literacy. The four steps of the development process included content and game mechanic development, game mechanic testing, content validity and communication of game elements evaluation, and usability testing. The game was tested and verified by experts in terms of its mechanics, communication, financial content, and implementation in two cycles. The experts included two gamers, two game designers, a finance professor, and two instructors as well as three high school students. The information from the first cycle will be used to improve the game, and the game was retested again in the second cycle. The qualitative data gathered through observations, informal interviews, and focus groups were analyzed using content analysis to determine the game's characteristics that were appropriate for classroom use and the effects of the game on students' skills and understanding of financial concepts. The results showed that the nature of the game should include a variety of gameplay options, each of which must be balanced to allow students to evaluate the worthiness of each choice made. The mechanics and components of the game must clearly demonstrate the relationships between the elements of financial concepts. Students were able to express their understanding of financial concepts and recognize their relationships. Additionally, the students expressed the use of mathematics in analysis and illustrated good decision-making during playing the game. The findings shed more light on the roadblocks that game developers will face and how to overcome them. Educators and teachers interested can apply the findings in this article to develop their serious games.

Keywords: Educational game development, Financial Literacy, Serious game, Fostering Financial concepts

1. Introduction

Nowadays, people have early access to financial services and financial products, such as paying for goods and services online, using a credit card, and taking out an education loan. Furthermore, financial products and technologies developed by financial organizations have become more complicated (OECD, 2012). Young people need financial literacy to solve current and future issues. Some countries, such as Australia and Canada, focus on improving financial literacy in schools by integrating it into mathematics and economics subjects. Thailand also modified the Basic Education Core Curriculum by including financial content into mathematics and economics classes. This change making it more conducive to the development of financial literacy. According to a survey conducted by the Bank of Thailand in 2020, Thai young people have more financial literacy than those in 2018. However, their financial behaviors, such as financial decision-making and appropriate money allocation for expenditures and investments, financial attitudes, regular savings, and setting long-term goals as the financial well-being are still issues (Bank of Thailand, 2020). Although the Bank of Thailand notes that financial literacy can be developed through informal education, such as studying from the internet or from telling by an experienced person, a study by Fürstenau and Hommel (2019) found that informal education does not impact on students' financial literacy if they lack foundation knowledge. Because the information is limited, their financial decisions are made based on experience by comparing with basic information. It is not in-depth processed and integrates new data and existing information. Therefore, school-based education that aims to provide students with the necessary financial knowledge and skills, as well as the ability to apply that knowledge in real-life situations, is still essential in developing students' financial literacy. Schools must provide quality tools and resources to develop students' financial literacy. These tools and resources must be consistent with the curriculum and flexible enough to adapt to students' abilities and backgrounds. These resources will help instructors implement them into their classrooms and allow students to learn from real or virtual circumstances in order to acquire financial literacy (OECD, 2012).

Simulation games are an effective tool for improving financial knowledge and abilities (Pfändler Andrea, 2021; Brennan and Vos, 2013; Cheng, Yeh, Chao, Lin, and Chang, 2020) because they allow players to practice making decisions in real-life situations that help students to develop the necessary skills for living and cultivating a

positive attitude. This includes understanding both the details and the big picture of social processes and the interrelationships between the various components that logically and systematically represent real-life situations (Stadsklev, 1974). Gaming can also trigger emotions such as curiosity, frustration, fun, trial and error, failure, and success (Kim, 2012; Buckley et al., 2016) and ponder every time you play. This is due to the fact that games can be replayed multiple times, resulting in the development of gameplay and a better understanding of the phenomena that occur within the game to achieve the game's objectives (Gee, 2011). The simulations used in the game should be accessible to students (Kiili, 2007), as they may have direct practical or educational experience, or indirect experience from what others say. As a result, the authors created a simulation game based on the assumptions outlined below.

1. Income, expendituresand investments refer to the options available in Thailandand the amount received and paid is based on the average amount and cost of living in Bangkok.
2. The financial literacy that students will gain from playing the game is considered when develop this game. In this game, the player must recognize the financial components' relationships and use the results of their actions to mathematically analyze and conclude the concepts they obtained.
3. The game must engage players to concentrate on making decisions.

This research aimed to develop and study the characteristics of simulation games that can promote financial literacy and can be appropriately applied in the classroom.

2. Background

2.1 Financial Literacy

Financial literacy can be defined in two areas: knowledge and understanding of financial concepts and the application of financial literacy (Huston, 2010; Remund, 2010). Financial knowledge can be considered in terms of the financial content and the cognitive level (Hill, Meszaros, and Tyson, 2011), and financial knowledge application can be considered as an aspect of competence that includes the ability to communicate a financial concept, aptitude for managing personal finances, the skills to make appropriate financial decisions, and confidence in effectively planning for future financial needs (Remund, 2010). The OECD defines the widely used definition of financial literacy as "financial literacy is knowledge and understanding of financial concepts and risks, and the skills, motivation, and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life" (OECD, 2020, p. 43). Therefore, it is the capacity that enables individuals to plan, implement, and effective control over financial decisions. Factors affecting decision-making include financial knowledge and skills, motivation, interests, attitudes, values, financial status, and environment. Both worldwide and domestic financial organizations have divided the content framework to establish standards that are income, purchases of goods and services, savings, credit and debt, investments, risk management, insurance, and financial decision-making (OECD, 2020; Jump$tart Coalition, 2007; CEE, 2011). This framework was used to design our 4 games to promote financial literacy: Wealth Creation, Saving and Investment, Credit and Loan, and Risk and insurance. In the game design, the financial decision-making model is considered as a key element in the development of financial literacy, as shown in Figure 1.

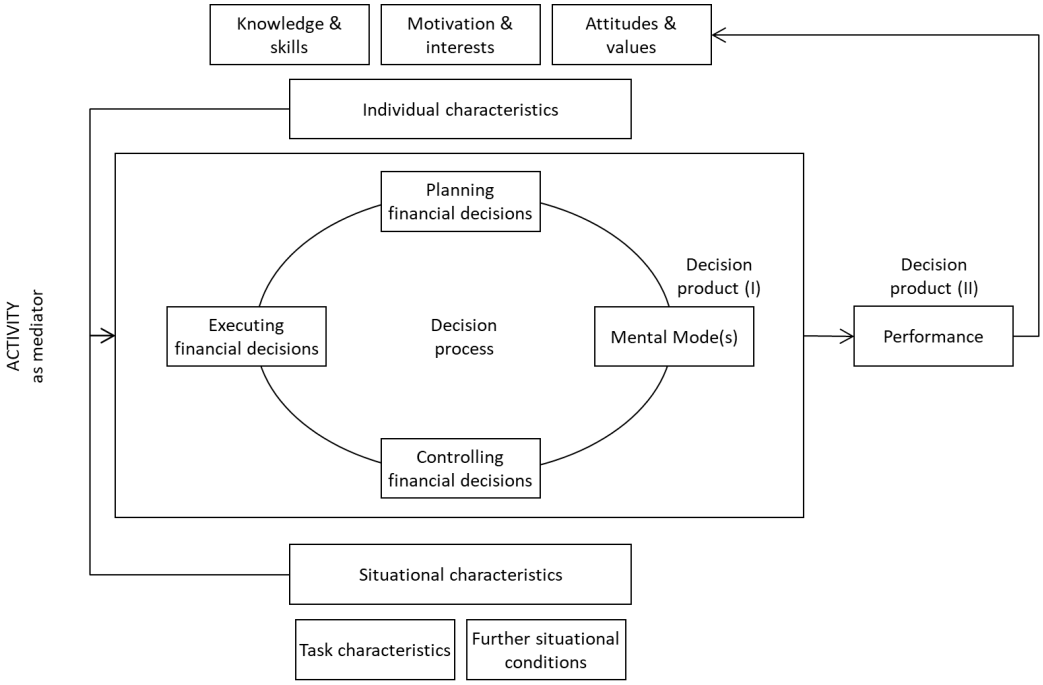


Figure 1: Game Components Competence-oriented working model of financial decision making (adopt from Ebner 2005)

2.2 Game-Based Learning

Game-based learning is the concept of using games for teaching and learning (Wilson et al., 2013) with a focus on interactive problem solving to achieve specific objectives while utilizing essential competencies. The students will receive immediate feedback after acting in uncertain situations in games to promote learning (Eseryel et al., 2014). Game-based learning is a student-centered approach to learning that combines content with games to allow students to develop various skills while learning content (Gee, 2014). Furthermore, while playing the game, players gain benefits in the following areas: cognitive (attention), motivation (flexibility in the face of failure), and emotional (emotional management), as well as social advantages, such as social behavior (Granic et al., 2014). Therefore, using games in the classroom is more effective in learning and long-lasting than other teaching methods (Woters et al., 2013). Games generally consist of mechanics, elements, stories, aesthetics, and technology (Schell, 2008). Game mechanics are game processes and rules that determine the game's goals, how the game is played, the story and sequence of events within the game, and the outcome of the player's actions.

The use of game mechanics with learning depends on the context of each player. Hence, learning games may not be attractive and motivating for all players Hamari (2014). Flow analysis examines a player's concentration and interest in what is happening while they are playing a game. It can be used to determine whether a game is suitable for a particular player. A player enters a state of flow when 1) they believe they are on their way to achieving a goal state, 2) they receive feedback on the outcome of their action, and 3) they are able to overcome the game's challenges due to their ability (Cziksentmihalyi, 1990; Schell, 2008). In a practical game, the game mechanics should have the following characteristics: 1) clear rules of play, 2) clear objectives and game complexity appropriate for the players, 3) interesting stories or themes according to methods of play, 4) difficulty level growing in accordance with the player's skill in the game, 5) interaction with players, 6) uncertainty level that the player cannot reasonably predict, 7) direct control, 8) providing feedback immediately after player actions, and 9) learning curve appropriate to the player (Aprea and Schultheis, 2019; Perotta, 2013; Shute and Ke, 2012; Cziksentmihalyi, 1990)

When compared to other one-way learning tools, games are one method for promoting financial literacy that is effective. Especially multi-objective educational games that encourage interactive play (Kalmi and Rahko, 2022). Many board games available today use the storyline within the game to explore the theme of personal finance. They can be divided into two groups based on the date of publication, classic board games and contemporary board games. The classic board games, such as Monopoly (1935), Game of Life (1960), and Cashflow 101 (1996), have a similar focus on managing income, expenses, investments, and savings for expenses from unforeseen

events, but with different emphasis. For instance, Monopoly emphasizes real estate investments and mortgages on land. The Game of Life centers on lifestyle decisions in education, career, marriage, and childbearing that affect income, expenses, and debt. Cashflow 101 emphasizes recording financial statements, which include income, expenses, assets, liabilities, cash flow, and asset management. Roll and move are frequently used as the primary gameplay mechanics in classic games, with additional gameplay mechanics like events, auctions, and loans. As a result, the main theme of the game revolves around the role that luck plays. Contemporary board games, such as Charge Large (2009), Stockpile (2015), and Pursuit of Happiness (2015) focus on complex cash and resource management and multi-step exchange based on the financial situation. Players must use strategies for both short-term and long-term play. Each game uses different mechanics as appropriate for the content used within the game. The Charge Large focuses on managing credit card debt and upholding credit. The Stockpile focuses on stock market news and investing in common stocks as well as assessing the worthiness of investments. The Pursuit of Happiness emphasizes allocating resources to achieve happiness in life. Many mechanics used in contemporary games require players to make the best assessments, plans, and decisions possible. Examples include worker placement, auctions, commodity speculation, markets, stock holding, loan investments, and open drafting. However, these games were all made with the intention of being enjoyable to play. Therefore, the purpose of this study is to create a game that can be used in the classroom and has a mechanism that is appropriate for promoting financial literacy in students.

3. Methodology

3.1 Requirements for the Specific Game Design

The game was developed based upon the characteristics of a game that promotes financial literacy, which was found in the literature (Aprea and Schultheis, 2019; Perotta, 2013; Shute and Ke, 2012; Cziksentmihalyi, 1990). It was as follows:

1. The content of the game is related to financial literacy development.
2. The game's mechanics and elements can be used to simulate real-world financial scenarios.
3. The game's difficulty level is suitable for the target group.

3.2 Aim of the Game and Game Structure

Wealth Creation is a game that demonstrates how to accumulate financial wealth. The game's goal is for players to collect as much wealth as possible. A player's wealth grows by investing their income to make a profit. Investments in each asset will have different returns and risks and its own set of liquidity. Each round of play will represent a different stage of life. The players can see the amount of expense compared to the amount of income in each round. The allocation of expenses in each round will affect the growth of players' wealth in the following round. In the beginning, the players will spend most of their earnings on necessities. As a result, the players' investment options are constrained. In the middle of the game, since the players earn more money by working and investing, the number of investment options has increased. Asset trading is a common practice for moving funds into higher-yielding assets. Finally, at the end of the game, the players can choose to sell high-risk investments to maximize their profit or decide to keep certain assets that are higher expected returns.

3.3 Game Mechanics

Wealth Creation is a resource management game that includes roll and move, open drafting, event, income, investment, and loan mechanics. Playing equipment consists of cards and dice that are used to perform activities related to income, expenses, stock prices, land prices, and unexpected events. The arrangement of equipment is shown in Figure 2.

Every player begins the game with 30,000 baht and three cubes to place on their income cards. The income cards separate into three types of employment: full-time, freelance, or temporary. The game is played in 4 rounds and each round is divided into five phases: 1) Expenditure phase is when players purchase goods and services cards, which each card having disc(s) and/or cube(s) representing working experience, knowledge and skills, and facilities. The cube is used for earning income and the disc is used for investment. Some goods and services cards can also provide social connections, opportunities to buy insurance, and financial wealth. The players must allocate their earnings to expensing and investment. 2) Investment phase is when players choose to buy or sell assets by using the discs. The assets that players can invest in include real estate, common stock, bonds, and gold. After the players used all their discs or all players pass their turns, the players can choose to place the cubes on the income cards they prefer. The number of cubes affects the credit limit for purchasing real estate. 3) Event phase is when the players are confronted with incidents, such as sickness, social connection

cost, asset disaster, and change in their investments. The Players, who have the opportunity to buy insurance initially choose to purchase health or asset insurance to transfer potential risks. After purchasing insurance, the dice are rolled. The value of the purple dice indicates the unanticipated expenses from the incidents. The yellow dice's value indicates the increase in real estate prices, and the blue dice's value indicates the change in common stock and gold prices. 4) The income phase is when players receive income from various sources, including working, real estate rental, dividends, and interest., 5) The loan interest phase is when players pay interest on real estate investment loans and credit card interest. When every player completes five phases, it is assumed that they finish one round., The new round is will begin. After four rounds, the points will be determined based on the value of the goods and services cards and the asset value. The player with the highest points will be the winner.

The authors designed the game mechanics to be consistent with the financial elements so that players can make decisions in the simulated scenario of creating financial wealth. A description of the design's mechanism can be found in Table 1.

Table 1: Details on the game mechanics in Wealth Creation

Mechanic	Financial concept	Action
Draw and select	Individuals must allocate their income for expenditure, investing, saving, and hedging.	Player selects three out of the five cards drawn for each round. Each card outlines actions relating to income, investments, insurance, and wealth.
Open drafting	Individuals can choose to invest in assets that match their risk tolerance and investment budget.	Players have access to a variety of asset options in a pool. Each type of asset has limits.
Income	People can make money in a variety of ways, including working and investing.	Players generate income from their invested asset cards and working cards.
Loan	Loans can be used for a variety of purposes, including basic living expenses and real estate investments. The interest rate on each type of loan varies.	Players may borrow money to use for events or to invest in real estate cards, but they must return the loan's interest before the end of the round.
Stock holding	Individuals can become wealthy by investing some of their income.	Players will receive returns in terms of dividends, interest, or capital gains.
Market	Common stock trading prices on stock exchanges are influenced by market demand.	When you purchase or sell stocks, the value of stocks will vary. When purchasing demand increases, the price increases, and vice versa.
Event	Spending and investment are influenced by the economy and government policies.	Players can purchase insurance to cover the cost from illness or property damage.
Protection	People can protect themselves against the possibility of losing their assets by purchasing insurance.	Players can purchase insurance to protect payouts from illness or property damage.
End game scoring	Wealth is defined as the accumulation of valuable economic resources that may be assessed in terms of either actual products or monetary value.	At the end of the game, the score will be accumulated from the value of cash and assets, such as real estate, common stock, bonds, and gold.

The design's financial features are based on the content structure displayed in Figure 3.

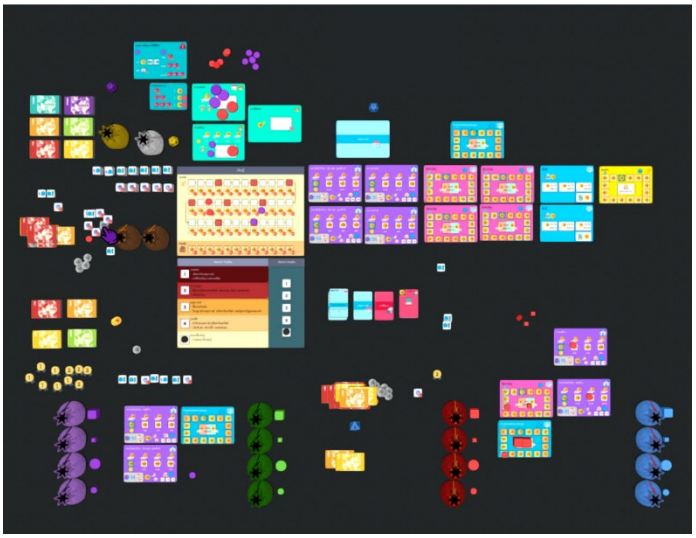


Figure 2: Game Components and Setting of Wealth Creation

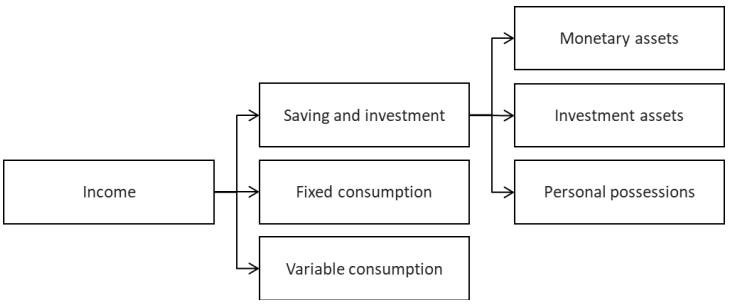


Figure 3: Content structure of Wealth Creation

3.4 Development of the Wealth Creation and Expert

The development and testing process is divided into four parts, as illustrated in Figure 4, with the following details:

1. Content and game mechanic development is a process in which the developers researched financial literacy and game mechanics and used them to design the game.
2. Game mechanic testing is a process that aims to test the game's flow and balance. The respondents were two gamers, aged 36 and 38, with bachelor's degrees. Both of them have played more than 100 different board games.
3. Content validity and communication of game elements evaluation is a process aiming to verify the financial content carried in the game. For content validity, the informant was a 38-year-old university professor from the Faculty of Economics. For testing the interpretation of financial elements and actions within the game, the informants were two game designers, aged 29 and 36, with master's degrees. They are game designers who have experience in designing more than 20 educational games and are trainers for developing an educational games.
4. Usability testing is a process aiming to test the suitability of the game for use in the classroom. The informants were two mathematics teachers at the school level, aged 29 and 27. To test the interest and knowledge gained from playing the game, the informants were three high school students, aged 16-17, studying at the upper secondary level. All three students never study economics and finance at the high school level.

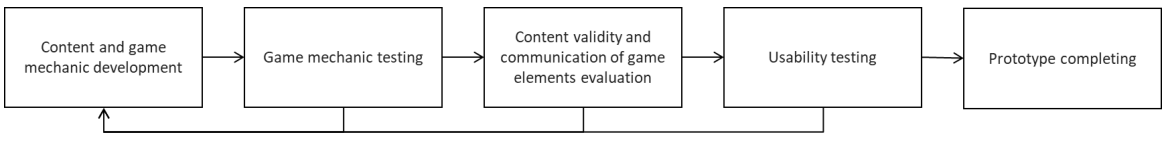


Figure 4: The development process

3.5 Data Collection

Researchers gathered information from the informants during and after playing the game through observations, interviews, and group discussions. The data were analyzed to characterize the game that suitable for implementation in the classroom and the influence of the game on students' financial abilities and knowledge. The coding scheme was based on the Serious Game Usability Evaluator (SeGUE) developed by Moreno et al. (2012). SeGUE is a method for assessing games based on the characteristics of serious games, which are divided into two dimensions: 1) The system dimension is divided into two sections: the interface section, which includes content, layout/UI, and technical errors, and the design section, which includes game flow and functionality. 2) The user dimension system is divided into positive feelings like pleasant, frustrated, reflecting, satisfied, excited, learning, and negative feelings like annoyed, confused, frustrated, unable to continue, and neutral feelings like giving advice. Furthermore, Ericsson's (1993) Thinking-Aloud method, which requires players to speak their thoughts and choices is used to determine the appropriateness of game elements during implementation and keep track of the players' moods and interests while playing the game.

4. Results

The authors encoded and categorized the data according to the system dimension in SeGUE, which is separated into interface and design. The authors also included the results of the students' responses. The results are as follows:

4.1 Results of the interface analysis

This section's analysis included content, layout/UI, and technical errors.

4.1.1 Content

There were seven positives, five negatives, and four neutral events discovered. On the positive event, the players revealed that they could learn how to play the game and attain goals within a single round of play. Because the game has a lot of content to be communicated, the players learned how to play through trial and error. When the players can link the elements of the game to the outcomes of their actions, they could continue playing the game without the assistance of the game master. A student player said, “in the first round, I didn't exactly know what to do, and needed an explanation from the teacher. However, after the first round, I had figured out the game's strategy and could continue the second round by myself". On the negative side, the intended message of the game was unclear to the players. The player could not perceive the whole picture of the scenario that should have been presented. As a result, the authors revised the game by using more specific words and using symbols to classify investments and expenses. For an unbiased opinion, the authors were suggested to balance the game and adjust the return on investment to make it more reasonable, such as "increase the attractiveness of investing in bonds and gold", "make real estate harder to sell due to asset liquidity conditions", and "adjusts common stocks to increased risk of loss as it is a high-yield investment".

4.1.2 Layout/UI

There were two positives, seventeen negatives, and eight neutral events discovered. On the positive side, the symbols for revenue and expenses are immediately understood by the players. The authors used the hand receiving the money symbol to represent revenue. The yellow coin represents the amount of revenue, and the red coin represents the expenditure paid in each round. This allows players to see where they can increase their earnings and where they must spend money in each round. On the negative side, the players were confused about the symbol representing the value of common stocks that show the price movement. Consequently, it took the players a while to notice the price movement. The authors then modified the game by using straight lines and symbols to represent the position of the trading price, including inserting arrows to determine the direction of price changes.

4.1.3 Technical error

There were three negative events. The players were bored and confused about the result of in-game actions and game balance, such as borrowing money to invest. The authors designed a short-term, high-interest loan mechanism in the case that the players do not have enough cash to deal with unanticipated events. However, because there were no clear terms of use and loan limits, some players borrowed money to invest in stocks and could win the game. While it is technically possible, content professionals did not want students to learn content in this manner. As a result, the authors determine the maximum loan amount that players can use each round and optimize asset liquidity and investment risk so that students can see for themselves why playing in this manner is not a good idea.

4.2 Results of the design analysis

This section's analysis includes the game flow and functionality.

4.2.1 Game flow

There were four positives, eight negatives, and three neutral events discovered. On the positive side, the players were excited with the return on investment because the game was designed for players to quickly increase their income. Thus, the players could invest money at the beginning of the second round. That the players could invest in assets multiple times allowed them to earn yields and still had money left for the next round. On the negative side, the players viewed that they could obtain the resource too easily, so it made the game uninteresting. Thus, they played the game without considering the value of their investment. "Why isn't it as easy to make money in real life as in the game?" is an example of a quote made by a gamer player. The authors modified the game by increasing the payout for every action in the game. It made the players have to plan every action more carefully. Every price for action results has an opportunity cost. For an unbiased opinion, content experts noted that players could easily create wealth in the game. In fact, there are other factors that affect wealth creation that prevents people from having good financial wealth in real life.

4.2.2 Game functionality

There were three positives, nine negatives, and three neutral events discovered. On the positive side, the players who made an early mistake can quickly correct their errors and rejoin the game because the game's objectives are clear. When a player was affected by an action that does not bring them closer to the target, they would be able to immediately change their strategies to minimize the disadvantage to other players. On the negative side, the players obviously see how to win the game, so they felt that the game was not interesting. For example, they increased their income from full-time work and then invested the money earned to enlarge their income. The player who makes the most money at the beginning is more likely to win. For an unbiased opinion, focusing only on earning and saving money for investments can make the game uninteresting. According to one gamer, "the game lacks variety in terms of playing technique. You have to follow the pattern of the game or you will lose". The authors revised the game by shortening the time required to build the salary base and expanding the sorts of jobs available base on their nature, allowing the player to select different types of income. In addition, the authors clarified the balance of return and investment risk and included a more diverse asset price range to enable the players more flexible investment plans. For an unbiased opinion, the authors were recommended to make multiple options in each component. As the development of financial literacy requires students to practice evaluation and decision-making in real-world situations, providing options is critical.

4.3 The results of the analysis of students' data.

The authors also had students test the game in order to evaluate its content communication. According to the data, the students exhibited their knowledge in 18 events. They were able to demonstrate their understanding of wealth creation in the exact way the author was designed. Examples of what a student says are, “in the beginning, it was not possible to invest much because income and expenses are almost equal. We will have more income in the middle of the game that allows us to invest more.” “Each investment gives a different return”. “Real estate is difficult to sell. In contrast to common stock and gold”. “There are certain commodities that give wealth, such as collectibles, watches, jewelry”. “We should have health insurance because medical expenses are expensive.” When the authors asked the students to clarify how they chose investments, they could demonstrate their value by using ratios and percentages to show the relationship between the principal invested and the return received, as well as the suitable investments for income level.

5. Discussion and Conclusion

In this article, the authors presented the results of the development of Wealth Creation, which is one of four series of financial literacy games for high school students. This series aims to teach the integration of financial literacy and mathematical knowledge. For Wealth Creation, the authors designed the game intending to give players a way to create wealth. The key concept is that wealth creation begins with properly allocating income and expenses to make money available for investment to increase returns. There must also be protections against wealth that may occur due to unexpected events. The study's findings revealed that the game's nature should include various gameplay options. Each option must be balanced for students to evaluate its worth. The game's mechanics and elements must demonstrate the relationship between the financial concepts’ elements. According to a study with students, the games engaged students to focus on the game, which resulted in the seriousness of evaluating various options within the game. It is one indicator of the game's integrity. In addition, the authors chose experienced board game players to be informants because we would like information to

improve the game in terms of game mechanics and its content. Hereafter, more extensive testing will be needed in other contexts, such as students with no prior experience playing board games and students from low-income families. The lean process is then used to cut unnecessary elements to make the game more concise and accessible. The necessary manuals, lesson plans, materials, and equipment will be supplied to assist teachers to implement board games in the classroom.

6. Limitation

However, there are some limitations in collecting data from testing during the development of this game. The authors created the game during the pandemic. Therefore, the authors had to put the game through its paces with an expert in an online setting, and the data collecting could only save data in audio format. If it could be a face-to-face interview, the author would be able to gather more information from the players' facial expressions and gestures—a more detailed analysis of data about emotions and feelings.

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Work in Progress Papers

The Design of a Gamified App for Supporting Undergraduates' Resilience

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Abstract: Supporting students in building psychological resilience is crucial considering the COVID-19 pandemic's effect on the population's mental health. Psychological resilience refers to finding ways to cope with stress and achieve goals despite obstacles. It is an important life skill that has become highly relevant in the post-pandemic era. Mobile devices and applications are becoming integral to users' self-monitoring of health data for their access, convenience, and cost advantages. Most resilience apps target specific professional groups, are not gamified, and lack solid theoretical foundations. Phone-based sensor data collected using Internet of Things (IoT) technology allow for new ways to measure psychological health and provide personalized recommendations. However, none of the existing gamified apps on resilience used IoT. None of the existing resilience apps refers to behavioral change techniques. The proposed resilience app addresses these gaps in the literature. This paper describes the design of a prototype for a gamified, theory-based mobile app that utilizes IoT to provide personalized data and support undergraduates' resilience in the "new normal" of the pandemic. The poster also provides preliminary data on undergraduates' feasibility and usability evaluation of the prototype, focusing on first-year students. Users set one of three goals daily (focusing on studying, engaging in physical exercise, and socializing), monitor their progress towards achieving them, and receive points and badges when reaching their goals. Goal setting, progress monitoring, and self-reflection at the end of each day are connected to a) self-reported data (e.g., through the use of a short, validated mental health survey that automatically calculates users' level of anxiety) and b) objectively measured data through the use of IoT (accelerometer and noise sensors) in the app. Users can share their badges on their social media networks. Thirty first-year undergraduates (M=18.41 years old, SD=0.57) tested the prototype resilience app and completed an evaluation questionnaire examining feasibility and usability. Neutral to positive responses (M=3.32 out of 5) were received for all functions indicating feasibility. Design usability was evaluated as satisfactory (System Usability Score=70.3). Future research will evaluate the app in a quasi-experimental setting. Implications for the design of gamified mobile apps for health are drawn.

Keywords: design for social change; gamified applications; resilience; COVID-19 pandemic; higher education

1. Introduction

During the COVID-19 pandemic, educational institutions were shut down worldwide, which impacted over 60% of students and caused a massive disruption of the education system. Studies conducted since the pandemic outbreak uncovered a significant elevation of COVID-19-related anxiety among students in European countries (Nicolaidou et al., 2021). The COVID19 pandemic is anticipated to result in long-term adverse mental health effects on the population (Golden et al., 2021). Therefore there is an urgent need to support students' psychological resilience. Psychological resilience refers to finding ways to cope in crises, overcome daily challenges, cope with stress, and achieve goals despite obstacles. It is an important life skill that has become highly relevant in the post-pandemic era.

2. Literature Review

Mobile devices and associated software applications are fast becoming integral to users' self-monitoring of health data for their access, convenience, and cost advantages. As the potential of smartphone apps and sensors for healthcare continues to expand, there is a concomitant need for open, accessible, and scalable digital tools, as are smartphone mental health apps (Torous et al., 2019; Nicolaidou et al., 2019).

A literature review revealed several attempts to develop and validate resilience apps within the last five years. Most resilience apps target adults belonging to specific professional groups (e.g., Litvin et al., 2020) and not the general public, are not gamified (e.g., Wood et al., 2017), and do not have strong theoretical foundations. Phone-based sensor data collected using IoT technology allow for new ways to measure psychological health and use them to provide personalized recommendations. None of the existing gamified apps on resilience used IoT, and none referred to behavioral change techniques. Moreover, prevention and wellbeing are underdeveloped in mental health apps.

The proposed resilience app addresses these gaps in the literature. It utilizes behavioral change techniques to support resilience as a prevention intervention by implementing a gamified approach combined with IoT technology that addresses the needs of a general, non-clinical undergraduate student population.

3. Design of the Student Stress Resilience app

The resilience app is expected to provide personalized recommendations based on user input in self-reports, the user's goal-setting, and sensor data (IoT) that allows real-time engagement. Three goals were deemed as the most relevant for students during pandemic lockdowns, based on the World Health Organization recommendations for mental health: focusing on studying, engaging in physical exercise, and socializing (Figure 1: tab Goals). Goal setting and progress monitoring are connected to the use of both self-reported data and objectively measured data through the use of IoT (accelerometer and noise sensors). Concerning self-reported data, users can take a short, validated mental health survey that automatically calculates their level of anxiety (Figure 1: tab Measure), and they can set and monitor goals related to studying (e.g., focused studying for 30 minutes). Concerning objectively measured data using phone-based sensor data, the app uses the accelerometer for the user to set and monitor goals related to physical exercise and a noise sensor for the user to set and monitor goals related to socialization.

Figure 1 shows goal setting in the "Goals" tab, self-reported anxiety test for the "Measure" tab, progress and badges in the "Progress" tab, and leaderboard, points, and ability to share progress on social networks in the "Social" tab.

The app generates reminders at a time the user chooses to engage, logs past app use, and has a simple and intuitive interface and interactions. Its prototype can be downloaded for testing.

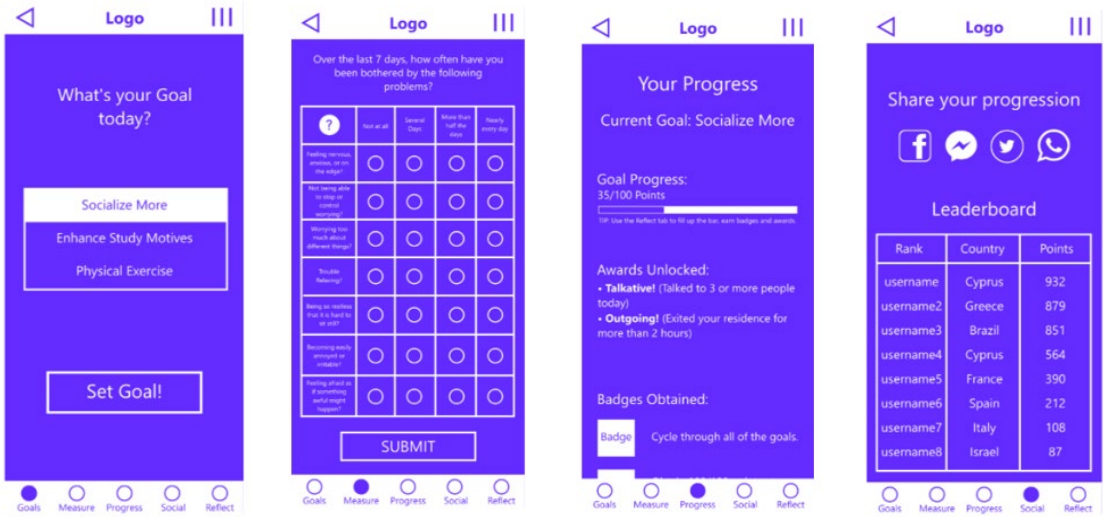


Figure 1: Screenshots of the prototype of the resilience app showing Goals, Measure, Progress, Social, and Reflect tabs

4. Evaluation of feasibility and usability

The evaluation of the prototype's feasibility was based on a questionnaire including ten statements using a 5-point Likert scale ranging from 1= "not at all useful" to 5= "extremely useful," evaluating each app functionality separately. It was completed after testing the app so that users could familiarize themselves with each demonstrated functionality before they were asked to evaluate it. The evaluation of the prototype's usability was based on the System Usability Scale, a standardized instrument that includes ten statements using a 5-point Likert scale.

In November 2021, 30 first-year undergraduates (M=18.41 years old, SD=0.57, min=18, max=20) tested the prototype resilience app face-to-face and completed the evaluation questionnaires examining feasibility and usability. Neutral to positive responses (M=3.34 out of 5, which is between "somewhat useful" and "very useful") were received for all functions indicating feasibility. Design usability was evaluated as satisfactory (System Usability Score=70.3).

Before this study, in April 2021, 74 participants (M=21.86, SD=1.78, min=18, max=24), most of whom were third/fourth-year students (86.5%, 64/74), tested the prototype and completed an evaluation questionnaire examining feasibility and usability. Positive responses (M=3.77 out of 5) were received for all functions indicating feasibility and acceptance of the design, and usability was evaluated as satisfactory (SUS score=72.5). The study was conducted online due to social distance measures and university closures imposed due to the COVID-19 pandemic (Nicolaidou et al., 2022).

A comparison between the two samples of students using an independent samples t-test showed that students attending higher years in university than the first year evaluated the feasibility of the app significantly higher (M=3.76, SD=0.82) than first-year students (M=3.34, SD=0.72) (t(99)=2.39, p=0.019). A correlation analysis including students of both studies (n=104) between their age (M=21.31, SD=3.02) and their evaluation of feasibility scores (M=3.6, SD=0.84) resulted in a statistically significant, moderate positive correlation (r=0.27, p=0.005). This finding indicates that older students who were potentially more mature and experienced in overcoming university life challenges were more inclined to appreciate the potential value of a gamified application for resilience.

Future research will evaluate the app in a quasi-experimental setting.

5. Implications for the design of gamified mobile apps

Mobile health apps often feature dense sections of psychoeducational text. To overcome this limitation, app designers can provide users with specific, brief, and accessible recommendations and resources using minimal text. App designers can embed validated mental health surveys that are easy to complete (e.g., GAD-7 in Figure 1, tab Measure) and can be scored automatically so that users can immediately receive an interpretation of their score. IoT can seamlessly provide data that can be valuable a) for the users to understand their routines (e.g., with respect to studying), b) for the developers to improve the app design, and c) for researchers interested in examining the effectiveness of mental health apps and their connection to behavioral change and learning.

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War game as a method of training – as a method of analysis

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Abstract: The purpose of the article is to present the development of a new simulation tool Superior Degree Demonstrator, which is intended to introduce the issue of fire support to students of the military college in a game-like manner. The simulator is intended primarily for the purpose of preparing future artillery officers at the Department of Fire Support of the University of Defence, which is directly involved in its development. At the same time, it aims to awaken in the younger generation of students a proactive approach to study. However, it can also be used as an objective tool of combat effectiveness analysis within the framework of the army acquisition programs.

Keywords: simulation, fire support, military training, combat effectiveness.

1. Introduction

Military exercises are an indispensable part of the training of members of the armed forces, which, in addition to their benefits, also entail a number of negative aspects. In particular, they involve economic costs, risks associated with threats to health, life or property and, last but not least, they can also have a negative impact on the environment. These negative impacts of the training can be largely eliminated by the effective use of currently available technologies in the form of simulations and trainers.

The advantages of simulation and trainer technologies are also shown in terms of making studies more attractive. The presented simulation tool Superior Degree Demonstrator (SDD) builds on the gamification of military college study using computer games such as Counter Strike and Battlefield or simulator Virtual Battle Space, which were implemented in the past at the university. Such a form of teaching has demonstrably not only professional benefits, but above all, it is a way of teaching that can be very attractive especially for soldiers of the younger generation.

2. War game

The preparation of members of the armed forces using the game principle is referred to as the War Game. NATO Alliance publication AAP-6 (2021) defines the war game as a simulation of military activity by any means using specific rules, data, methods and procedures. The war game is primarily carried out for the purpose of selecting the optimal variant of the solution of the tactical situation and its possible training based on the available forces and means. Within the war game variants of the solution are created, their consequences are assessed and based on them the best option is selected or certain measures are taken.

For this purpose, a number of simulators have already been created and are also used by the Czech Army. However, a number of simulators, which the Czech Army possesses, deal only with the overall tactical situation on the battlefield with a focus on combat units and they miss the specifics of using combat support units. It is for this reason that the University proceeded to the acquisition and development of a new military simulator with a focus on fire support.

The issue of fire support includes, in particular, the control and coordination of ground and naval artillery and close air support for the benefit of its own combat units. In a very simplified way, this process can be imagined as the work of an air traffic controller at an airport, who is subject to similar requirements in terms of safety and efficiency. It is essential that the military personnel responsible for this activity have adequate training. Such roles are dealt with in the original research at the university (Nohel et al, 2022).

3. Methodology

Software development was preceded by the evaluation of experience with training and simulation technologies used in the past at the department. At the same time, the current available simulation software, which the university possesses, was evaluated, especially MASA Sword by YTEK company. A literature analysis was also carried out with a focus on application areas of the research carried out at the university and its implementation into the software was evaluated.

At the moment, the simulator is still in the software development phase. Nevertheless, it was intentionally delivered to the department at an early stage of development in order to take into account its effective progress in a specific direction that is required by the University. Qualitative research methods, such as brainstorming or narrative interviews with fire support experts collect data for further development of the simulator in terms of potential teaching benefits. Similarly research is carried out with students, but in terms of "entertainment side" of simulator which is taken into account in the development as well.

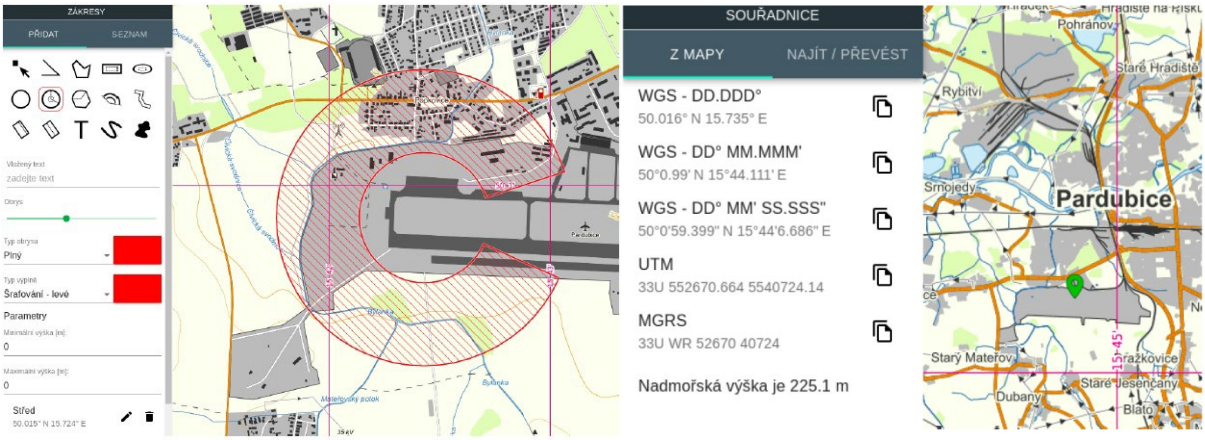
4. Superior Degree Demonstrator (SSD)

The Superior Degree Demonstrator is one of the simulation tools of the war game currently being developed directly by the Department of Fire Support of the University of Defence. The main task of this new military simulator is to provide an attractive form of presentation to students of the military college on the issue of the combat use of artillery. The SSD tool consists of a server on which the RePlan software application is located and any number of wirelessly connected computers on which the application subsequently works.

The university cooperates with the company RETIA, a.s. on the development of this simulator and the name of RePlan software is derived from the name of company. The company has long cooperated with the Czech army in the field of research and development of defence technologies with a focus on, among other things, radiolocation means or command and control systems.

4.1 Method of training

The software application RePlan has the ambition to become a comprehensive 2-D fire support simulator, which currently works with a number of geographic products with high resolution. These are raster maps, vector and elevation data for the whole territory of the Czech Republic, which allow a number of analyses through the available tools. Basic map tools allow students to work with the map base, measure distances, areas, read coordinates in a number of defined NATO formats. Movement issues are related to various research activities at the University (Vlkovský et al., 2021).



Another current benefit of the RePlan application is the drawing of tactical icons according to the standardized NATO symbolism and their management within tactical situations. The simulator allows to add units that interact with geographic layers. This allows to perform terrain analysis for deployment of units, radar or weapons range analysis based on visibility due to the terrain. Within the artillery is also useful terrain profile analysis for detecting obstacles on the flight path of the projectile, for determining artillery fire data. The RePlan application further allows battlefield analysis from the perspective of targeting. The icons of enemy units can be marked as targets of the strike and according to their characteristics, the RePlan application evaluates these targets in terms of priorities and order of elimination.



The current state of the simulator allows for training of students in working with electronic map in command and control system in unclassified mode, choosing the right units and relevant tactical icon. From the tactical point of view, it allows training in filed survey and emplacement of units, as well as plot of combat formation or intelligence preparation of battlefield or issuing of operational orders. To a limited extent also coordination of fire support from the position of fire support officer. That means of tracking own or enemy units, observe safety distances during a firing missions or prioritization of targets.



Graduates of the military university take up command and staff positions that form the core of the military command and control system (C2). For this reason, it is necessary, among other things, to familiarize them with the principles and algorithms of C2 systems before coming into practice. C2 systems are operated in a classified mode in the environment of the military and the DNS tool thus allows work with these systems in a non-classified mode (Šilinger & Blaha, 2017).

The future intentional state is to create a complex simulator similar to MASA SWORD, which does not have a sufficiently elaborate issue of fire support. This means to allow complex interaction between units of own and enemy. Furthermore, automatic or automated evaluation of tactical situations depending on the set parameters. From the point of view of attractiveness for students, it seems like a prospective competition between students. From the point of view of the quality of the evaluation of situation by students or even simulation of combat activity between them. As well as their cooperation in the combat and coordination of fire support and possible

involvement of virtual reality. From the pedagogical point of view, it is intended to create standardized operational scenarios on which students' knowledge and abilities will be tested in terms of speed and accuracy of decisions.

4.2 Combat Efficiency Analysis Method

Based on the possibilities of simulation tool in creating and evaluating war game scenarios, a secondary but equally important function of the SDD tool can be identified. The war game method serves primarily to select the optimal variant of the operation solution based on input parameters. Applying this principle offers the function of the simulator to analyze effectiveness of the combat formation based on available or allocated means. The input parameters of the simulation can be adjusted e.g. in terms of the quantity of units, armaments, their capabilities, etc. and the results can be compared. The initial results of the research have already been published (Blaha & Potužák & Šilinger 2018; Ivan et al., 2021).

In the same way, it is possible to change the input parameters in the sense of changing the combat devices to those that the army does not currently possess and monitor their influence on the course of the operation. Such a way of measuring efficiency based on the given parameters of the evaluated devices enables evaluation of new acquisitions and verification of the effectiveness of their purchase. It should be noted that the combat activity is a stochastic process into which a large number of variables enter, and the results of the simulation are always dependent on the quality of the simulator processing.

5. Conclusion

The battlefield is constantly evolving, both in terms of the accelerating pace and in terms of the spectrum of means and systems used. For this reason, there are also higher requirements for members of the armed forces, which the university must take into account in the preparation of future army staff. The issue of combat or fire support evolves with each conflict and it is therefore necessary to maintain the pace of this development not only in terms of systems and means, but also in terms of the preparation of members of the armed forces responsible for this area. Experience from the preparation of the current generation of students of the university indicates a lack of a proactive approach to study. These reasons lead to the implementation of presented simulation tool SSD which can serve not only for training purposes but can be used for evaluation of course of action as well.

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Late Submissions

Let's Jazz: A Case Study on Teaching Music with Educational Escape Rooms

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Abstract: Escape rooms have been proven to be a functional game-based approach to teach a variety of subjects. Teachers as well as students are eager to play escape rooms in the classroom; field studies have demonstrated how escape games are a memorable activity with a high retention rate, especially if followed by a proper debriefing session, in which learnings emerged and are made consistent. In recent years literature on educational escape rooms has grown, yet there is little body of research on educational escape rooms on music education. In this paper we present an educational escape room about Afro-American music at the beginning of the past century. The players are asked to solve a murder case happened in the backstage of a jazz club in New Orleans. Such scenario gives the players/students the opportunity to "experience", within the escape room context, cultural and historical details and characteristics related to this musical genre. The puzzles within the escape room are formally related to jazz and Afro-American music, giving players/students the possibility to learn and have a "first-hand" experience with concepts that would otherwise remain purely theoretical within a normal classroom environment. Learning has been measured by the means of a 3-step test design: the pre-test was administered before playing the escape room, the first post-test was administered right after playing the escape room and before the debriefing, while the second post-test was administered two weeks after the debriefing phase. From a qualitative point of view the teacher has noticed high motivation while playing the game, with respect to a normal classroom activity. The quantitative results of the second post-test have shown students have retained many of the concepts presented within the escape room and this highlights the importance of a debriefing phase to consolidate learning after playing an educational escape room.

Keywords: Educational Escape Rooms, Music Education, Game-Based Learning

1. Introduction and background

Educational Escape Rooms (EERs) as a game-based learning activity have become popular in the past few years, especially in higher education. While many EERs have been studied in higher or adult education (Fotaris and Mastoras, 2019; Mijal et al., 2020; Veldkamp et al., 2020), only a limited body of work explores EERs in middle-school, primary school or kindergarten (Fotaris and Mastoras, 2019; Hod-Shemer and Dabush, 2020; Babazadeh and Frigerio, 2021).

Subject matter is also an issue. The popularity of platforms such as Breakout EDU (Rouse, 2017) has helped the spread of EERs in class, yet with a strong unbalance towards scientific disciplines, which apparently more easily fit within such a game framework. Indeed, there is still lack of research about the effectiveness of EERs for subjects such as music or the arts. Even Breakout EDU[1] only offers about five escape rooms that include "music", and only three of them are actually focusing on music and music theory.

Learning in an escape room – like in most game-based approaches – is motivating and memorable, but is often unaware, as the concept of stealth learning suggests (Sharp, 2012). While the fun and excitement of the game remain in the foreground, the acquisition of new knowledge and skills might fade to the background: mastering game-based learning requires experienced teachers (SchoolBreak, 2019). In most game-based learning approaches the debriefing phase is when the learning that took place during the game is addressed, elicited, commented and integrated with previous learning and in the overall instruction (Betrus and Botturi, 2010).

The goal of this paper is twofold: on the one hand, we present an EER in Music Education for lower secondary school students, contributing to the collection of evidence about the educational use of escape rooms in non-scientific disciplines and with young students; on the other, we designed a 3-step assessment in order to collect insights about the actual role of debriefing in the learning process.

[1] Search performed on the Breakout EDU website the 27th of April 2022 at 15:39.

Our hypothesis was that before playing the EER students would have minimal knowledge on the subject matter. Right after playing the EER, we expect students to have only partially acquired new knowledge, which during the play phase is decontextualized from the overall learning path; eventually, after re-contextualizing it during the debriefing, we expect students to have consolidated their knowledge.

The paper is structured as follows: Section 2 describes the methodology: the design and rationale behind the EER, the experimental group, and describes how the experiment was designed. Section 3 describes the play phase and the debriefing phase of the EER. Section 4 presents the results of the tests and how the class performed before and after the debriefing, while Section 5 concludes the paper.

2. Methodology

The EER in Music Education presented in this paper was developed by a secondary school music teacher as a game-based learning activity to consolidate knowledge on jazz and Afro-American music. Given the lack of materials on the subject, the teacher decided to design his own EER following the Star Model (Botturi and Babazadeh 2020) as part of his Master Thesis on Music Education. On the one hand, the teacher was interested in studying the development of a EER on Music Education; on the other hand, attention was paid to the role of debriefing after having played an EER.

2.1 Designing the escape room

A typical EER spans over two class periods: one for playing and one for debriefing – not much time, so that the achievable learning objectives should be few and very clear. The overall instructional goal of the EER is to teach and consolidate knowledge on the topic of jazz and Afro-American music. To operationalize this goal, the teacher focused on the learning objectives listed in the official curriculum plan (DECS, 2015), in particular in its *"rappresentazioni, culture e percezioni"* ("representations, cultures, and perceptions") section. In particular, the teacher focused on treating characteristics and formal aspects of Afro-American music:

- Recognize instruments used in the context of Afro-American music
- Understanding the structure of the musical form and being able to describe it
- Classify styles and assign the correct social role to each of the observed styles (i.e., *Worksong* and *Spiritual*)
- Recognize the pentatonic scale and its extensive use in Afro-American music

Relevant content items were transformed into puzzles and organized in a *game-flow* for the players to explore in order to solve the EER. The narrative of the EER took the form of a thriller involving detective Brian Duke, who was tasked to find the culprit of a murder happened in a Jazz Club in New Orleans in the backstage of a concert. The EER starts with the players being asked to help the detective find the killer.
Section 3 illustrates in detail how the EER is played.

2.2 The experimental group

The study involved a second-year middle school class (ages 12-13) in the Italian-speaking part of Switzerland, composed by 13 females and 7 males pupils. The class is described as a heterogeneous group with different skill levels, which influenced how the subgroups were formed by the teacher during the play phase. Some of the students manifested mature and disciplined behaviour, while few others exhibited provocatory behaviour towards the teachers. During the play phase these difficult cases were grouped with quiet students in order to reduce the risk of misbehaviour.

At the beginning of the study the class had no prior knowledge of Afro-American music history and theory, and never had any lecture about Afro-American and jazz music, so that it was reasonable to expect rather low scores in the pre-test phase.

2.3 Experiment description

PHASE 1. Pre-test. To measure the impact of the EER on students' knowledge of Afro-American music, we decided to perform a pre-test to assess prior knowledge on the matter. Given the fact that there are no standardized tests on the subject matter, the pre-test was created by the teacher and included eight questions about jazz and blues, including their origins and their musical characteristics (instruments, musicians, structure, musical measures, etc.). The test was administered at the end of October 2021.

PHASE 2. Introduction to content. After PHASE 1 the teacher gave an introduction on the content, providing the students with the basic tools to understand what they were going to face during the EER in terms of subject matter. In particular, students were faced with micro-problem situations and derive conclusions which were analysed in class with the help of the teacher to contextualize the learning. This learning unit started in November 2021 and was concluded in January 2022.

PHASE 3. The educational escape room. In the first week of February 2022 students played the EER. Right after playing, the same test as the pre-test was administered to assess if students grasped some of the learning aspects of the EER and recall what they had seen in class before the debriefing.

PHASE 4. Debriefing. During the second half of February 2022 the teacher performed the EER debriefing with the students. This was done to contextualize what they have seen during the EER and solve misconceptions.

PHASE 5. *Final assessment.* Eventually, during the second week of March 2022 the second post-test was administered to measure how much the students understood and recalled after playing and after having received the EER debriefing. The post-test contained the same questions as the prior tests in a different order.

3. Let's Jazz

The EER foresees two groups that play at the same time; the groups have similar puzzles with different solutions and have to collaborate to find the solution of the final puzzle.

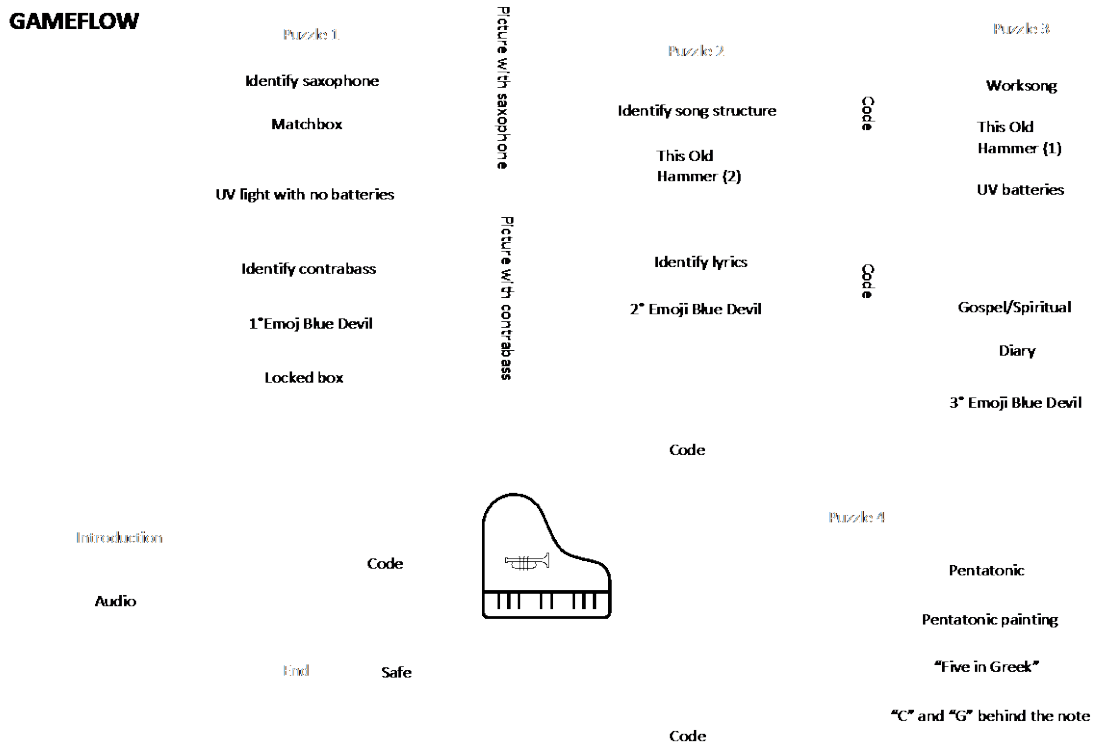


Figure 1: EER Game Flow.

Figure 1 shows the game flow (Botturi and Babazadeh 2020) of the EER. The grey boxes represent the puzzle areas. Each grey box contains smaller blue outlines which represent the puzzles the two sub-groups have to solve; in each outline the green box indicates the solution needed, while the orange boxes indicate elements or hints within the Puzzle area.

Puzzle 1. To access Puzzle 1 both groups have to find a missing disk "slice" and solve a musical puzzle (Figure 2). The solution found is a password to access a crypted PowerPoint presentation on which players can find an audio file (Puzzle 1). In Puzzle 1 players are asked to recognize an instrument being played within the PowerPoint

audio. The purpose of this Puzzle is to recognize musical values, musical instruments, and indirectly introduce faces and names of jazz music cornerstones such as John Coltrane and Miles Davis.

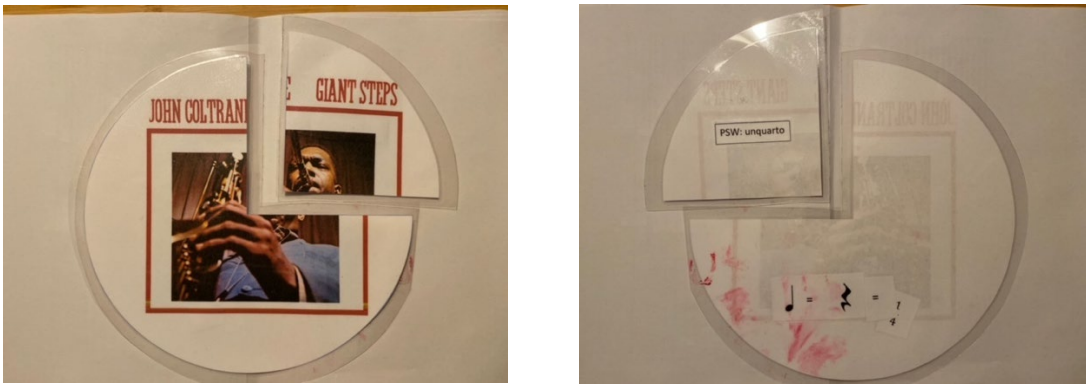


Figure 2: The solution to access Puzzle 1 for group B after the disk "slice" has been found.

During the resolution of Puzzle 1, Group A finds a matchbox with part of the solution of Puzzle 4 written with invisible ink, and a UV flashlight without batteries. During the resolution of Puzzle 1 Group B finds a locked box with no keys and an Emoji stained with lipstick behind which some lines of the lyrics of a famous Blues song are written.

Puzzle 2. To access Puzzle 2 both groups have to look for a picture portraying a detail of the instrument they recognised in Puzzle 1, behind which they can find the music sheet of a jazz song which will lead to Puzzle 2.

In Puzzle 2 group A finds a fragment of a music sheet of the work song *"This Old Hammer"*, behind which they can spot the word "Responsorial" (clue) in invisible ink. To solve this puzzle, players are asked to find the structure of the song. Group B finds another Emoji with lipstick stains; on its back they can read another fragment of the lyrics and are asked to find the name of the a famous Jazz rhythm. The solution for group A to access Puzzle 3 is "AABA", that is the formal structure of many jazz songs, while for group B is "SWING".

Puzzle 3. In Puzzle 3 group A finds the second fragment of the music sheet of the work song *"This Old Hammer"* and the batteries for the UV flashlight. Group B finds the third and last Emoji with the rest of the lyrics; Figure 3 shows the three Emojis players can find. Group A is now able to read the hidden words written with invisible ink on the matchbox and on the music sheet fragments giving access to Puzzle 4. Group B instead can recognize the lyrics and can derive the structure "AAB", which helps open the locked box found in Puzzle 1. In the box, players find the key to access Nole King secret diary, found in Puzzle 4 (Figure 4).



Figure 3: All three Emojis group B had to find.

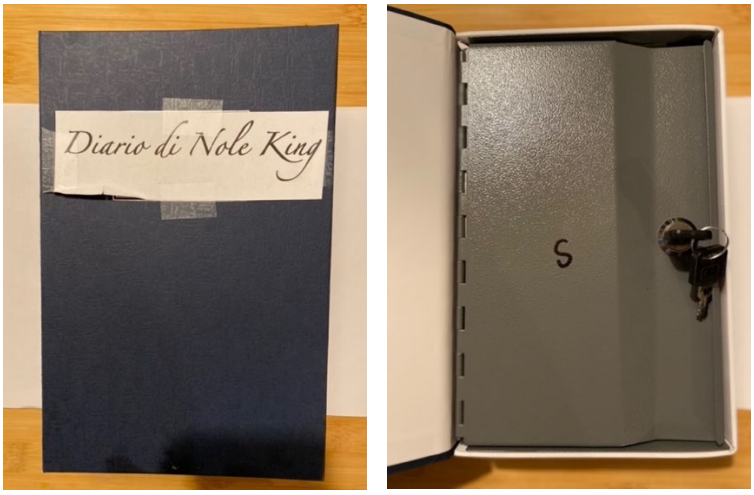


Figure 4: Nole King's secret diary.

Puzzle 4. To solve Puzzle 4 both groups have to put together the hints they found while solving the previous puzzles. Group A has obtained the last two letters of the combination, which were written on the matchbox (G A), while group B finds the letter "C" written with a lipstick behind a note in Nole King's diary. On the piano, available in the room, players are able to spot a lipstick stain on the "C" piano key. There are other hints for this puzzle, such as a painting with a pentatonic scale and a note hanging on the wall that says "five in Greek" ("*Pente*" reminding of pentatonic). By combining the C note and the last two letters, G and A, players realize these notes are part of the pentatonic scale, which they need to perform on the piano. The pentatonic scale becomes the key (the teacher acknowledge the correct key input sequence) to open the last box, a safe, which contains the narrative resolution of the EER: journal articles describing what happened that night at the Jazz Club.

3.1 The play phase

The idea of playing an escape room was well received and students were excited to play. For this study, in order to allow the active engagement of each student, during the play phase the class was divided in two groups which played two parallel instances of the EER. The two groups were further divided into the two sub-groups previously described (Group A and Group B) composed each by four or five students. The groups were created by the teacher in order to have balanced and heterogeneous groups, avoiding teams only composed by stronger or weaker students.

The game performance was very uneven: the teacher reported that while some groups managed to complete their path much earlier than expected, other groups found some puzzles difficult and could not get to the solution without help.

The teacher observed that, in the groups that worked better, a leader coordinated the work, so that every group member had his or her opportunity to propose and test a solution; in this way the puzzles were solved through collaboration. The groups which did not work well were lacking such a leader figure: every group member tried to brute force their solution without thinking and without communicating with the others. In some cases, there was just one member actively trying to solve the puzzles while the rest of the group simply watched, which resulted in frustration and discouragement.

These observations were confirmed by a game assessment survey that was administered right after the debriefing. The instrument included 6 items to be assessed on a 5-point Likert scale ranging from "Completely disagree" (with a value of zero) to "Completely agree" (with a value of 5). The items included self-evaluation and soft skills assessment on how the players performed in a team, if they found it easy to follow instructions, and if their mistakes during puzzle resolutions were understood (Table 1).

Table 1: Game assessment test questions

#	*Statement*
1	I know how to cooperate effectively as a member of a team
2	I remember the important parts of the Escape Room
3	I find it easy to follow instructions or take orders from others
4	I had fun playing the Escape Room
5	I understood the instructions of the teacher
6	I understood my mistakes

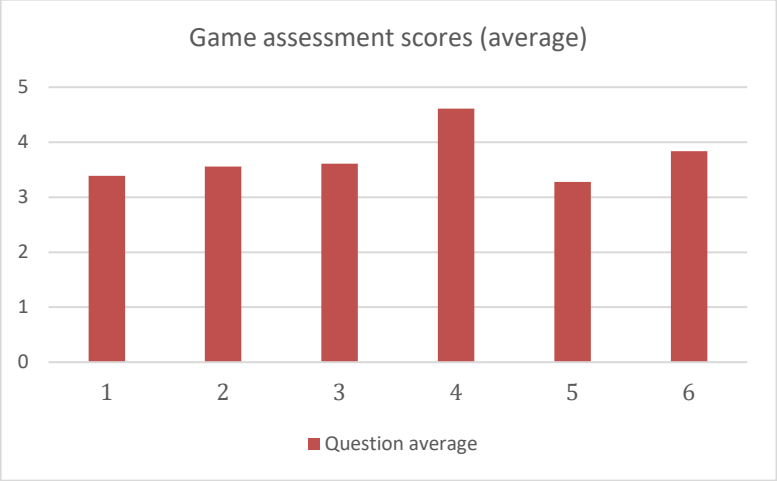


Figure 5: Weighted average of the answers for the game assessment survey

Figure 5 shows the weighted average of the answers for each of the six questions administered with the game assessment survey. As we can see most of the students enjoyed playing the EER, confirming the observation of the teacher during the play phase and the debriefing phase. Interestingly enough, students seem to have understood their mistakes during the play session, confirming the importance of the debriefing and the consolidation of their subject matter competencies. On the other hand, the instructions of the teacher before the play phase seemed not to be so clear for some students (item number 5), suggesting a better introduction of the play phase could be done by the teacher.

3.2 The debriefing phase

During the study, the debriefing phase was very important to consolidate, contextualise, and conceptualise the learning. It was structured in three steps.

STEP 1. EXPRESSING FEELINGS. At first, students had the chance to express their feelings about the gameplay. Everybody had a positive and memorable experience, even though some students felt stressed and frustrated during some puzzles, especially the students which did not have a collaborative group. As expected, students were excited mostly because of the collaborative aspect of the experience, rather than for the possibility to learn something new through the game. Indeed, as such game-based learning experiences diverge from standard classroom learning, students have the chance to enjoy a different learning mode while playing with their peers. This was true especially for those who collaborated well during the game phase and managed to solve the puzzles with their groups; students in non-collaborative groups reported that the experience was not as positive but memorable and fun nonetheless.

STEP 2. CONCEPTUALIZING LEARNING. After the first unstructured step, the teacher started conceptualizing the learning, asking the students how they solved the various puzzles, and reframing with some misconceptions that arose. The teacher focused on some details of puzzles that most of the students overlooked, for example the characters portrayed on the disks in Puzzle 1. In fact, only few students paid attention at the musicians on the disks and retained that information. This also arose in the first post-test, where students, even though having played the EER, had difficulties naming three famous jazz musicians. During this phase the teacher went into details as who these musicians were and how they become cornerstones of this musical genre. The same happened for the definition of terms such as "riff", which was still unclear.

STEP 3. FORMALIZING LEARNINGS. After analysing each puzzle, the class wrote a summary of the EER where they identified various definitions for each topic in the subject. This structured phase helped the students to keep track of what has been seen and recap the major aspects of the subject.

Overall, the teacher observed that the debriefing helped contextualising what has been experienced during the EER and this was reflected in the second post-test, where students demonstrated that the concepts were indeed solidified and better understood. The following Section presents the test results to support this claim.

4. Results

Each of the 3 tests had a maximum of 39 points that could be scored by replying correctly to all eight questions. Each question had a different maximum score, from one to five points, depending on the difficulty of the question and the expected length of the answer. Table 2 shows how the points were computed for each question.

Table 2: Evaluation rubric for students answers on the tests

Answer	**Scored points (%)**
Complete and correct answer	100%
Correct and non-complete answer	75%
Partial answer	50%
Incorrect answer	25%
No answer	0%

By the means of the evaluation rubric in Table 2 we were able to assign each student to a class (low/medium/high) for each of the tests (Test 1: pre-test; Test 2: post-test right after the EER; Test 3: post-test after the debriefing). The "Class" column represents the range of scores in the test: the "LOW" label represents a score lower than 50% of the maximum points achievable, the "MEDIUM" label corresponds to a score within the range of 51% and 70%, while the "HIGH" label represents a score higher than 71%.
Table 3 shows the scores in percentage of the tests and the average score per group category.

Table 3: Average and results of the pre-test and the two post-tests. Two students did not attend the session in which the Test 3 was administered.

Class	Test 1 (%)	Test 2 (%)	Test 3 (%)
HIGH	0	25	66
MEDIUM	0	45	34
LOW	100	30	0
Average score	9.50	58.35	73.72

By confronting the pre-test and the first post-test, and the first post-test and the second post-test, we can immediately see a performance improvement for all students (with the exception of one student which underperformed in the second post-test with respect to the first post-test). The percentage of the "LOW" class shifted from 100% in the pre-test to 30% in the first post-test. Most of the class shifted towards the "MEDIUM" range while some students managed to achieve to fit within the "HIGH" score range (25%).

This suggests that the introduction on the concepts plus the consolidation through the EER had a positive effect on the subject matter competencies. Even more so if we take a look at the difference between the first post-test and the second post-test. In the second post-test we see that all the students managed to achieve a score above the 50% of the total points (no students appear in the "LOW" class). 34% of the students managed to fit within the "MEDIUM" range while most of the class, 66%, managed to achieve a score that fit within the "HIGH" group. The change in the average score (last row of Table 3) summarizes the growth of the class in terms of subject knowledge. The average is computed after having normalized the scores to a scale from 0 to 100 for better clarity.

The Sankey chart in Figure 6 depicts the evolution of the scores in the three tests. The three colours represent the test scores classes: red represents the "LOW" class, yellow represents the "MEDIUM" class, while green represents the "HIGH" class. The number besides the labels in the diagram indicate the test, "1" for the pre-test, "2" for the first post-test, and "3" for the second post-test.

The leftmost vertical line shows that all the class got a score less than 50% during the pre-test, when the class still had to be introduced the topic. The middle vertical line shows the results of the first post-test, right after the EER has been played. Some of the students managed to retain some information after the play phase, with only six students achieving less than 50% ("LOW" class) and five students scoring more than 71% ("HIGH" class). After the debriefing, students managed to contextualise the contents of the escape room and clarify some doubts, this is shown on the results of the second post-test, rightmost vertical line, where no student scored less than 50% and six students remained in the range 51%-70%. The two missing students are shown as "N/A" on the diagram.

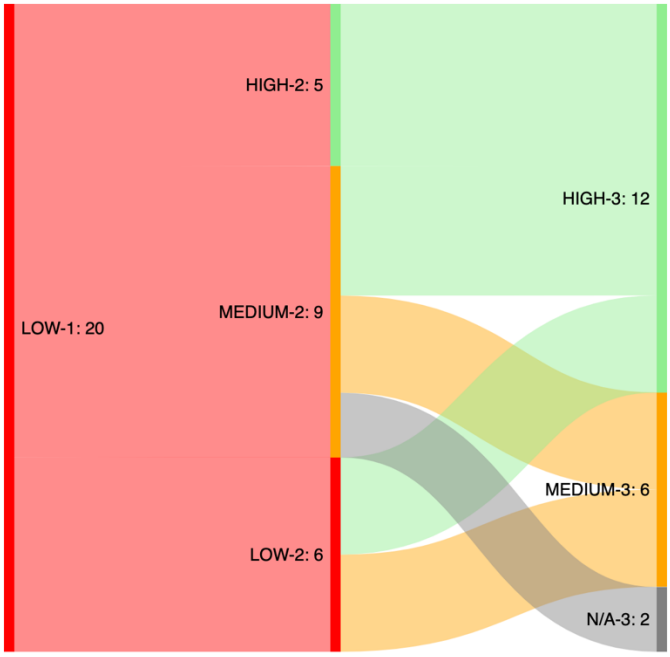


Figure 6: Sankey chart showing the evolution of the scores during the three tests

Figure 7 shows the mean delta variation and standard deviation delta variation across the three tests. We computed the difference of the normalized scores for each student from pre-test to the first post-test ("post-test 1"), from the first post-test to the second post-test ("post-test 2"), and from the pre-test to the second post-test. Then we computed the mean and the standard deviation of the result.

For every student the difference between the pre-test and the first post-test has a positive delta, meaning that on average all the students scored better in the first post-test than in the pre-test. This comes as no surprise as the pre-test was done right before any introduction of the subject. The same observation applies to the delta between the first post-test and the second post-test. Except for one student, everyone else managed to obtain a positive delta, thus improving their score from the first post-test.

The delta between the pre-test and the second post-test suggests that there was an increase in subject knowledge. Students managed to learn from the introductory lectures and if on the one hand the play phase helped with self-evaluation by testing their knowledge while discovering something new, on the other the debriefing phase conceptualized and contextualized this learning which was then integrated.

The teacher described the high retention rate as a primer for this class, which motivated the application of such game-based learning activity in the future.

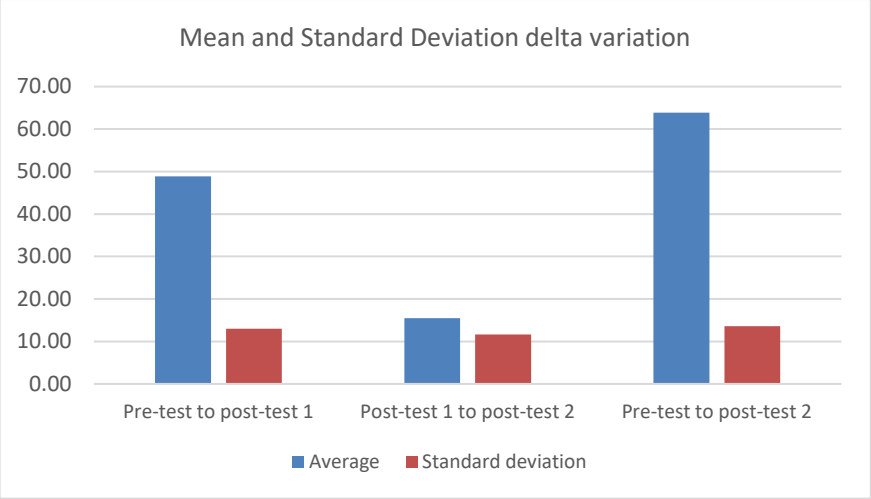


Figure 7: Mean and standard deviation of the delta across the tests.

5. Conclusion

In this paper we presented an educational escape room (EER) in Music Education for lower secondary school students about jazz and Afro-American music. This work contributes to the collection of evidence about the educational use of escape rooms in non-scientific disciplines and in lower secondary education.

Students were presented with a pre-test to assess their knowledge on the subject matter, then were introduced by the teacher on the subject by the means of micro-problem situations. Students played the EER and were administered a first post-test to assess their knowledge after the subject introduction and the play phase. After having debriefed the play phase, the teacher conducted a debriefing and administered a second post-test to assess if there are differences in student comprehension and understanding of the subject.

Quantitative results suggest that the introduction of the subject and the play phase helped most of the students improve their knowledge, while the debriefing contextualized and consolidated it even more, improving the scores of the students on the second post-test. In fact, most of the students (66%) managed to achieve more than 71% of the total score in the second post-test, while only 25% of the students managed to achieve such score in the first post-test.

Qualitative results derived from teacher observations confirm that EER are fun and enjoyable for students, which find such game-based learning activities memorable with respect to standard classroom activities. Quantitative results provide insights on how students perceived the experience, suggesting it also helped improve soft skills, and on the importance of the debriefing phase.

Unfortunately, this study was conducted on only one class. Further research could use an experimental design, and could better study the motivational and learning impact of the EER in Music Education and in lower secondary education. We expect the double-post-test design proposed in this study to generate relevant evidence to shed light on the learning processes associated with ER-based learning.

A focus on student profiles might also be helpful to identify the characteristics that makes students more prone and ready to learn from escape games at school.

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Digital Escape Games in Educational Programs for Financial Literacy

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Abstract: Escape from the Castle is a digital escape game created with the collaboration of the Museum of Saving in Turin (Italy), Neuroscience Lab Intesa Sanpaolo Innovation Center, and the GAME Science Research Center of IMT School for Advanced Studies Lucca. In the escape game, players must help Mica, the mascot of the Museum, to run away from the Ghost of the Baroness, from its Castle. To do that, every player has to solve four puzzles in four different rooms. Each room is correlated to a financial issue, such as saving strategies and planning. The game aims to increase the awareness that money represents a means for achieving a purpose (i.e., use value of money) and not an end, from a behavioural and neuroscientific point of view. So we built a study about the behaviour of teenagers. According to the literature, the cooperative approach proposes emotional and cognitive involvement as a tool to strengthen learning, increases awareness of self-efficacy and, when applied to money management, increases the self-perception of being able to make consumption choices. To better understand the mechanisms of cooperation, we built an experiment with 118 students from eleven to fourteen years old, that played the game during a visit to the Museum. We divided students into two groups: one in which students could collaborate with each other in solving the puzzles (treatment) and one in which they had to play individually (control), and we collected score and time of play (behavioural data). In each group, two students wore eye-trackers to record pupil dilation to collect neurophysiological data. Here we present mainly the behavioural results that show that the students who were allowed to collaborate obtained, on average, double the score compared to those who played individually. Furthermore, those who collaborated finished the game in less time than those who have not played as a group. Moreover, combining behavioural data with neurophysiological data, there are indications that high pupil dilation is correlated with high engagement in play, and this is often true in collaborating groups.

Keywords: escape games, museum studies, financial literacy, collaboration, learning, game-based learning

1. Introduction

Escape from the Castle is a digital escape game created with the collaboration of the Museum of Saving in Turin (Italy), Neuroscience Lab Intesa Sanpaolo Innovation Center, and the GAME Science Research Center of IMT School for Advanced Studies Lucca. The possibility to promote financial literacy using games has been extensively investigated (Paeßens & Winther 2021), also highlighting numerous attempts applying games (Richards et al. 2015) that try to bridge the financial literacy gap by using games and video games in teenagers and youngsters (Rasco et al. 2020).

Financial literacy could have a great boost through play or gamification, especially for lifelong learning. The game pushes towards autonomy, an increase in motivation, and improving support structures to ensure that lifelong learning and decision-making are managed effectively through an evolving system (Rasco et al. 2021).

Another aspect is what concerns the use of escape games. In recent years, escape games have also been investigated as tools for game-based learning (Fotaris & Mastoras 2019), with many examples of escape games for education (Veldkamp et al. 2020), including digital ones (Makri et al. 2021).

There are various fields in which educational escape games are used, including computer science at university level (Borrego et al. 2017), food education (Yachin & Barak 2019), just to give some examples, and more generally all STEAM disciplines (Karageorgiou et al. 2019), while there are just few examples of escape game used for economic arguments (Martina & Göksen 2020).

In the case of *Escape from the Castle*, we have not only designed a game, but also a research tool, as well as an interactive location inside the Museum of Saving in Turin, Italy. With *Escape from the Castle* we ran a neuroscientific and behavioural experiment about behaviours related to money saving and the role of collaboration in learning, in teenagers. According to the existing literature (Bandura, 1997), the cooperative approach proposes emotional and cognitive involvement as a tool to strengthen learning and favours the development of social skills in interactions between peers. For teenagers, these skills can help to build problem-solving abilities. A cooperative approach increases awareness of one's skills / abilities (self-efficacy) and, when applied to money management, can increase the self-perception of being able to make consumption choices effectively to be able to achieve one's own goals (about self-effectiveness, Tsang et al. 2012). In conditions of uncertainty, individuals with greater awareness of their abilities are more likely to reduce impulsive or impatient behaviours that, in general, make it more difficult to carry out personal projects related to savings and investment. In other words, a high level of financial self-efficacy favours intertemporal choices (between now and tomorrow) that are more reflected and, usually, more favourable in terms of economic output.

In this study we have run an experiment, through a neuroscientific approach, to understand if learning by solving problems with an escape game in a cooperative setting is better than in an individual setting, particularly in regard of financial literacy.

1.1 Design of the educational escape game

Escape from the Castle is a digital escape game developed by the research team that aims to increase financial self-efficacy in teenagers through collaboration between peers. In a more general sense, the game aims to increase the awareness that money represents a means for achieving a purpose (i.e., use value of money) and not an end, from a behavioural and neuroscientific point of view.

Escape from the Castle has a mediaeval setting, designed to engage participants with a series of puzzles and riddles that require the use of creative and logical thinking to solve them.

In the game, players have to help Mica, the Museum's mascot, to escape from the Ghost of the Baroness' Castle. To do that, each player has to solve four puzzles distributed in four different rooms of the castle. Each room is correlated to a financial issue, such as saving strategies and planning; for example the puzzle in the Library is correlated with savings planning.

The castle is divided into the following rooms: the lobby, the kitchen, the lounge area, and the library. Each room is associated with a different riddle correlated with different financial topics, such as saving strategies and planning. The lobby room contains a text comprehension connected with financial topics. Participants have to fill white spaces with the missing letters and understand the meaning of the text. In the kitchen, participants are presented with a recipe book and a series of ingredients; given the scarcity of resources, they have to choose the cheapest ingredients to cook one of the receipts written in the book. Participants receive a series of furniture used to renovate the room in the lounge area. The total cost of the furniture is too high, and players have to choose which elements to remove to be within the budget. Lastly, in the library, players have to put in the correct order a series of books. Each book contains a specific phase of saving planning.

Once logged in the game, players enter the lobby and have to solve the first riddle. After that, participants can decide, without a specific path, which of the other three rooms they want to enter. Once entered into the room, they can exit and re-enter as many times as they wish. In each room, once you have solved a puzzle, you get an object and victory points to add to the gaming score. Moreover, they have the possibility to ask up to two clues for each room, knowing that asking for a clue halves total points for that specific room. Also, succeeding to finish the game in 15 minutes grants extra points on top of the accumulated ones. Players are allowed to solve all the riddles in a maximum of 20 minutes.

The game was first designed between May and September 2020 and developed between October and December 2020. The game was playtested with teenagers of the same age as the target of the game, from 11 to 14 years old.

2. Research methods

The study was conducted at the Museum of Saving in Turin, Italy, an interactive museum that explores aspects and concepts related to the issues of saving, money and investment. Intervention materials were designed by the GAME Science Research Center partners, which comprises researchers and developers from the IMT School for Advanced Studies Lucca in collaboration with Neuroscience Lab Intesa Sanpaolo Innovation Center.

The project involved two secondary middle-schools and their students, aged between 11-14 years old. Each player was identified with an alpha-numeric code that guarantees the anonymity of the collected gaming data and makes it possible to connect them with data from the questionnaires. Six secondary classes from the middle-schools in Turin were recruited based on teacher interest. All participants were randomly allocated, within their classes, to one of the two experimental conditions. Students were accompanied to the museum by the teachers. Background questionnaires were administered in each school one month before the intervention in the museum, precisely in February 2021. The questionnaire was designed to cover different topics: ludic habits, propensity to collaborate in groups, and financial literacy. It also served the purpose to collect demographic and scholastic information, such as age, gender, and average mark.

The parents of students involved signed an informed consent form, with the specific consent for the possibility to link students' answers to their scores in the program. The study was reviewed and approved by the local IRB.

2.1 Experimental conditions



Figure 1: Materials used during the experimental sessions at the museum.

The six classes participating in the experiment visited the Museum during three days of May, namely the 4th, the 5th, and the 6th. Each class arrived at the museum at a different time, and the visit lasted 2 hours. Once arrived, each class was divided into three groups of eight, which participated separately at three experimental sessions, each lasting 40 minutes. When called for the experimental session, students of each group were randomly divided into two experimental conditions: the individual (control group) and the cooperative (treatment group) condition. The two groups were physically and acoustically separated in two different rooms in the Museum. The two rooms were cautiously set to have a similar level of brightness. In the control group, students were seated far apart from each other, and they were not allowed to communicate between them. On the contrary, in the treatment condition, students were seated in front of each other and were allowed to communicate without any limitation. These rules were part of the experimental instructions that were read aloud by the experimenters in each of the two conditions' rooms. Participants could ask clarification questions before starting playing to ensure complete comprehension. In both settings, each student received an iPad with the escape

game application already opened and ready to start the game. Two students in each condition were randomly selected to receive an eye-tracker to record pupil dilation data. Experimenters supervised for the entire time the two groups, without intervening but available in case of technical problems.

In the meanwhile, for each class, the remaining two groups of eight visited the museum, until they were called by the experimenters to start their session. Students of the same class belonging to different groups were unable to interact during the visit to avoid pollution of the experimental sessions by any kind of anticipation.

The ad-hoc design of the videogame allowed us to collect experimental data on its use, i.e. score and time. Both scores and times were available as a total for the whole game, and as partial values attached to each riddle. Overall, during the experimentation at the Museum, we thus collected behavioural data from the videogame, as score and time of play, and neurophysiological data through the eye-trackers.

2.2 The gamified retention phase

After the experimentation at the museum, students were again allowed to play the escape game online by accessing a dedicated reserved area on the Museum's website. They received instructions on how to play the online version at the end of the experimental session at the museum. The online game was playable at any time without limits during a four weeks period that ended at the beginning of June 2021. These four weeks represent a retention phase, where students could reinforce their learning through repetition by voluntarily engaging in further sessions of the game. The online version of the game was slightly different from the one played at the museum. It contained the same environments but riddles inside each room were different to stimulate thinking abilities and thus keeping the game challenging. Each riddle was designed in up to three different versions. When starting a new game, for each room, one out of the three possible riddles were randomly selected by the software. Our experimental design for the retention phase consists in having two different approaches between the two schools to investigate the effect of gamification on young students' engagement and learning. In one of the two schools, students were informed that when playing during the retention phase, the leaderboard would have been updated weekly with the points accumulated in the online games, thus potentially changing the ranking. Moreover, they were informed that, at the end of the four weeks, the final ranking would have determined a podium with the winner, second and third place, and that qualifying at these positions would have granted a special recognition by a symbolic prize. On the opposite, students from the other school were given no prize and no ranking information at the end of the gaming period. Their leaderboard was thus not updated weekly and the only ranking they were able to check was that obtained during the experimentation at the museum. This experimental setting allowed us to investigate and test the role of incentive schemes provided by gamified systems when voluntarily playing an educational game.

3. Results

A total of 118 students are enrolled in the project. The average age of the sample is 12.4 (SD 0.92) and 45% are females. Summary statistics by treatment and control groups show that the two groups are well balanced in both age (Z=-0.625, p-value=0.532) and gender (Fisher's exact test, p =.467) composition. Moreover, as shown in Table 1, no statistically significant differences are found between groups regarding average marks received at the end of the last scholar year, previous escape game experience and how much they play video games, suggesting that random assignment to the treatment group produced balanced samples.

Table 1: Average difference of control and treatment groups in the background questionnaire

Variable	Control	Treatment	Min	Max	T-C Diff. *p*-value
Age	12.40 (0.92)	12.48 (0.88)	11	14	0.532
Female	0.45 (0.50)	.52 (0.50)	0	1	0.467
Av. Mark	7.21 (0.97)	7.16 (0.97)	5	9	0.946
Escape Games	2.21 (1.33)	1.86 (0.95)	1	5	0.297

Variable	Control	Treatment	Min	Max	T-C Diff. *p*-value
Video Games	3.21 (1.48)	2.80 (1.24)	1	5	0.139

Note: Age is the students' age. Female is equal to 1 if female, 0 otherwise. *Av. Mark* is the average mark students obtained at the end of the past scholar year. *Escape Games* is a 1-5 Likert scale from "*Never*" to "*A lot*" on how much students play escape games. *Video Games* is a 1-5 Likert scale from "*Never*" to "*A lot*" on how much students play video games.

Figure 2 shows the average score obtained by participants (left chart) and the average time, in minutes, spent to complete the game (right chart). Looking at the average score obtained by participants in the control group, it is around 25 points, against the 43 points obtained, on average, in the treatment group. The Mann-Whitney test rejects the null-hypothesis that the difference in the average score between control and treatment groups is equal (Z= -4.710, p <.001). On average, the treatment group obtains around the double score reached by the control group. Looking, instead, at the average time each participant takes to complete the game, we find that, on average, participants finished the game in around 19.4 minutes in the control group while, in the treatment group, they were able to finish it 1 minute earlier, around 18.5 minutes. However, this difference in time is not statistically significant (Z= 0.758, p=.448).

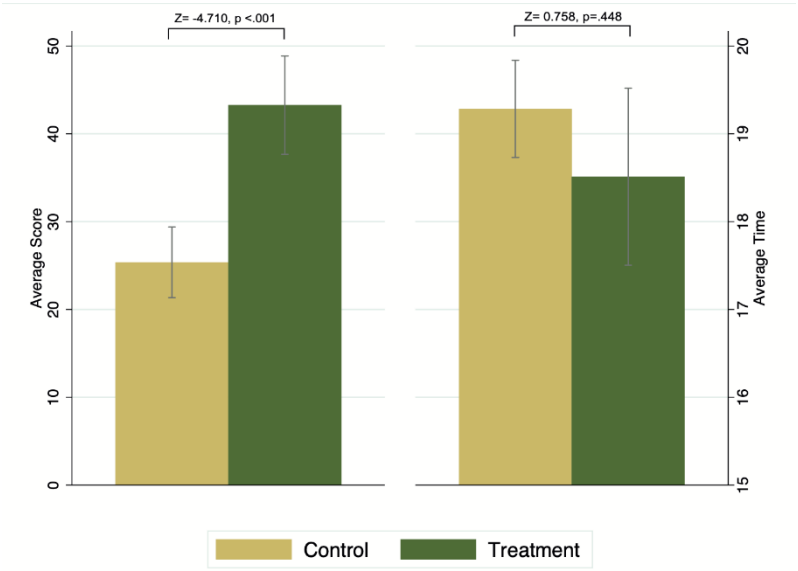


Figure 2: Average score obtained by players (left chart) and average time in minutes for completing the game (right chart) in the control and treatment groups

It might be interesting to understand if the effect on the final score is given by a specific score reached in one or more riddles of the game or if the score obtained in some riddles, depending on the difficulty, were not so different. Figure 3 shows the average score obtained in each room divided by treatment groups. As shown in the figure, no difference is found in the lounge area riddle (Z= -1.051, p=.403). On the other hand, statistically significant differences are found in the lobby (Z= -3.225, p<.001), in the kitchen (Z= -4.783, p<.001) and in the library (Z= -3.539, p<.001). These findings suggest that, depending on the difficulty of the riddles, cooperation sometimes works better than individual activities, other times same results can be achieved also without cooperation.

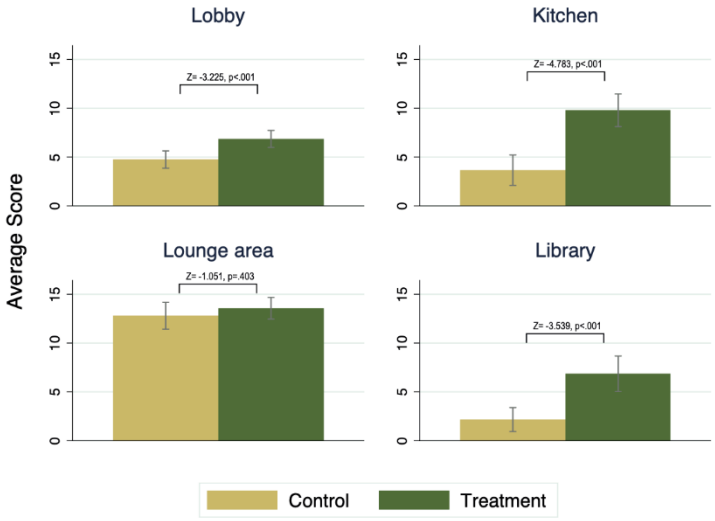


Figure 3: Average score obtained by players in the control and treatment groups by rooms

Finally, only 40% of the participants in the treatment group were able to conclude the escape game within the limited time, meaning that completing the entire game was not so easy. On the other hand, looking at the percentage of students in the control group who escaped from the castle, only 15% of them reached the end.

3.1 The retention phase results

Based on the data collected during the retention phase, only 20 students out of 118 played the escape game during the four weeks after the visit to the museum. Among these 20 students, 18 belong to the incentivized setting (treatment group) and only 2 are from the school without incentives (control group). The total number of sessions of the game played by the treatment group is 154 against the 3 sessions played by the students in the control group, suggesting that the role of incentive schemes provided by gamified systems worked properly.

At this point, one might wonder whether playing the game more times increases the final score obtained by students, which is in line with the results found by Erhel & Jamet (2013). In their experiment, they show that giving feedback after each game, participants performed better on comprehension, underlining the role of feedback on triggering deep cognitive processes that contribute to better learning (Sweller et al., 1998).

Figure 4 shows the average score obtained by students on the sessions played online. Given that most of the 20 students played at least 2 games, but only few played more than 3 times, we averaged the final score of the games after the 2 in only one score (third column of the chart). The Kruskall-Wallis test rejects the hypothesis that the average score in the sessions played during the retention phase are equally distributed (X2= 9.323, p=0.009). Looking at the difference between the first and the second session played, the Mann-Whitney test confirms that the average score significantly increases by around 20 points (Z=-2.647, p=.007). This suggests the efficacy of the learning-by-doing approach and an increase in the knowledge about the game and the financial aspects presented in the game.

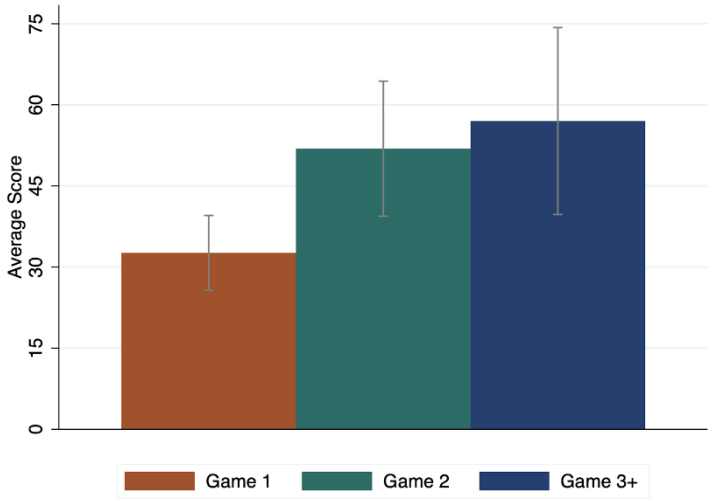


Figure 4: Average score obtained by players during the retention phase in the first (Game 1), second (Game 2), and following (Game 3+) sessions of the game played

4. Discussion

The data collected indicate that collaboration increases the performance in the game, both in terms of the score and in terms of the resolution time of Escape from the Castle; indeed groups that collaborate finished the game with higher scores on average and faster than those who play alone.

Results confirm the important role of collaboration in the process of using a game, in problem solving, and also in the learning process. These was also underlined by other studies (for example Troussas et al., 2020; Hämäläinen et al., 2006; Zhang, Q., & Yu, Z., 2021), which highlighted how effective construction of game tools is essential for developing collaborative learning (Hämäläinen et al. 2008). Precisely in the case of Escape from the Castle, the data reveal how the tool works better with a collaborative approach to the game, rather than playing alone, at least during the first game session and within a museum environment, i.e. when the possibility of repetition is very limited. The second phase of experimentation, concerning gamification, has highlighted instead that repeating the game several times (even with randomized and never the same puzzles), allowed individuals, playing alone, in achieving excellent results.

Numerous ideas can be made to explain why collaborative groups had higher scores. The exchange of ideas and therefore the conversation is one of the factors that could make the most difference and this would seem to be confirmed by observing the game groups. Escape from the Castle is comparable in many aspects and within our experimentation to an interactive museum location. It is therefore clear that it follows the same directives, especially with regard to informal learning, as well highlighted in the literature (Hein, 2002; Falk & Dierking, 2016) with numerous examples of projects (Solima, 2018; Rowe et al., 2017; Cesário et al., 2017). In the case of informal learning, conversations between participants usually allow information to be rebounded and a common solution to be reached together, which is not possible alone. The resolution of the puzzles is also closely linked to financial content; therefore, it is presumed that learning is better in the collaborating subjects, both for a greater exchange of information and for a better gaming experience. The escape game was chosen precisely to evaluate this aspect: understanding how to solve puzzles (and therefore the content, closely linked to the puzzles) is a difficult solo test.

Secondly, the gamification experiment. Even if the students who participated were not many, the game sessions were numerous, especially in the school with incentives. This underlines how important it is to think carefully about all the elements of gamification in order to help a learning process (Sailer & Homner, 2020). The interesting element is that with each new game session the score increased on average and the resolution time decreased on average, this also considering that the puzzles were randomized at each new game session. This seems to indicate that with each subsequent game there was a better understanding of the game and therefore indirectly a learning of the contents of the game.

Finally, the neurophysiological data collected with the use of eye-trackers is very interesting, but extremely difficult to analyze. Preliminary results seem to indicate that those with greater pupil dilation also achieved higher scores. Additionally, there appears to be a significant difference between pupil dilation in the first half of the play session and in the second half. These data could indicate a greater involvement in collaborative groups compared to solitary players, who failing to solve the puzzles independently, gradually deconcentrated, losing motivation and engagement. Unfortunately, the neurophysiological data are not easy to read. The real difficulty was collecting clean data in an experimental setting, the museum, which was very difficult to standardize. Furthermore, the short time available did not help to collect clear data right away. Precisely for this reason it was decided to continue the experimentation and try to go deeper using EEG (Electroencephalography) to better understand what happens during the game session, using a laboratory setting that is much easier to standardize.

5. Conclusion

Escape from the Castle is now a multimedia exhibit in the Museum of Saving in Turin, as well as an app that can be downloaded from the iOS and Android stores. This game is an example of how careful design can allow you to create a useful tool in a museum to build engagement with visitors and at the same time a useful tool for scientific research related to learning and behaviour. If on the one hand the multimedia exhibit is finished, on the other hand, scientific research will not be closed yet. The project plans to collect behavioural data on cooperation trying to further expand and diversify the sample, following the example of other virtuous projects (Bilancini et al. 2021), involving schools other than the initial ones. Unfortunately, Covid-19 has made it very difficult to collect data within a museum, but the end of the health emergency can help research, easing the imposed limitations and allowing the sample to be enlarged. For this reason, the experimentation will continue by repeating a data collection in some schools near Lucca, Italy. The power of collaboration, which Escape from the Castle promotes, needs to be further investigated in order to have bigger and more solid samples and to analyze the issue even more in detail. Many aspects of the game can be interesting ideas to reflect on; for example, careful game design can help improve collaborative skills (Brandt & Messeter, 2004) or push to learning and training about skills related to problem solving and collaboration (Sánchez & Olivares, 2011). Language, conversation during play and how it is addressed seem to be determining factors in encouraging learning through play (van der Meij et al. 2011). The same thing happens in a very similar way in museums with regards to learning related to exhibits (an example of conversation for learning in Haden, 2010), underlining how there is a strong parallelism about informal learning between games and museum locations.

Another fundamental aspect to be explored is that relating to the increasing engagement as a conduct for learning. In particular, finding a quantitative signal that can indicate from both a behavioural and neuroscientific point of view when and how a subject is more focused on an educational activity then will allow to build a series of design elements capable of pushing learning more effectively.

Precisely to this, it is also important to continue experimentation on the neuroscientific side. Unfortunately, Covid-19 has strongly limited this part of the research and therefore a neuroscientific experimentation will also be carried out on young adults with other neuroscientific investigation tools such as EEG to go into more and more detail.

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The Burden of Choice: Using Games to Teach Ethics as a Skill

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Abstract: Learning and teaching ethics often presents a series of challenges that are not found in other topics. In order to teach (and learn) ethics as a skill, descriptive approaches are often not enough, and a more direct experience to ethically-relevant situations that prompts for subjective reflection is needed. Examples of relevant scenarios might be used to strengthen the learning of ethically-relevant matters, but even in these cases, the spectator is still a sort of "back-seat driver" with no agentivity. However, interactive media, such as digital games, can sometimes require the player to decide, up to a point, the way a fictional story is tailored. This added agentivity can allow for the appearance of a feeling of responsibility towards choices and outcomes, and can be helpful to foster genuine reflection on the ethically-relevant dimension behind. This paper explores how different game design approaches can be used to prompt genuine ethical reflection in their players. This exploration focuses on the design of meaningful choices, attachments and spaces for reflection as the key elements in order for a game to be used as a gateway to learning ethics by subjective exposure. The paper starts by considering how different techniques have be used in commercial games in order to do create genuine moral involvement. The insights taken from these considerations are then applied in the design and implementation of a prototype of an interactive narrative, currently under development, aimed to be used as a complementary tool to teach (and learn) ethics as a skill.

Keywords: ethics, ethics learning, game-based learning, moral gameplay, interactive narrative

1. Introduction and Motivations

Ethics is an important part of education that appears in the syllabus of practically every professional and higher degree courses. Nevertheless, ethics is sometimes reduced to a set of legalistic regulations and therefore ethics ends up being refurbished into mere compliance. This approach falls short in terms of learning ethics as a skill that could to be incorporated in the everyday mindset of current and future professionals in order to both identify and mitigate potential ethically-undesirable effects, as well as to recognize and exploit ethically-desirable ones. Nevertheless, and as it is argued in (Casas-Roma et al, 2022), ethics is understood as a skill requires a combination of an understanding of the relevant *ethical principles*, an *awareness* and a *sensitivity* towards the nuances of the particular context, and *empathetic recognition* of the patients that might be affected by the outcomes, as well as the *reasoning skills* needed to foresee potential consequences and balance the ethical dimension of a decision with other conflicting interests and tensions.

Even though these abilities can be conceptually understood from a theoretical point of view, being able to apply these abilities in a practical context is needed in order to train them --just as with any other skill. The use of real-life examples (Biedenweg, 2013; Soudek, 2018) and fictional settings allow to explore ethically-relevant scenarios; nevertheless, non-interactive scenarios (be them based on real cases, or fictional) still leave the student "outside" of the scenario as a sort of "back-seat driver" with no agentivity. Some forms of interactive fiction, such as narrative-driven games, can be a tool to reach beyond the role of the "observer" and give agentivity to the player. As such, games and interactive narratives can be a valuable tool to complement the teaching of ethical competences.

This paper follows up the initial design considerations of a prototype of an interactive narrative, introduced in (Casas-Roma et al, 2022), that aims to use techniques from game design to prompt genuine ethical reflection on their players. Section 2 presents some existing techniques that commercial games have used to create moral gameplay and discusses how to aim towards the players' genuine involvement; Section 3 exemplifies how some of these insights have been incorporated in the interactive narrative prototype, and discusses some challenges and first directions towards a way of evaluating the effects of this narrative. Section 4 provides some concluding remarks and points to further lines of work.

2. Fiction, Moral Gameplay and Genuine Reflection

Even if they are not real, stories of fiction have always been able to prompt a wide range of emotions in their audience and through many different formats, such as books, movies, or theatre plays, to name a few. Nevertheless, the spectator is still "separated" from the fiction and is kept outside of it, with no power over the events that happen within it: in other words, they lack interactivity. Forms of interactive narratives, like choose-your-own-adventure books, their movie counterparts (such as Netflix's *Black Mirror: Bandersnatch*), or

narrative-driven games (either digital, or tabletop) provide the spectator (which, in those cases, might be already referred to as the "player") with the opportunity to provide their own input to determine how the story may move forward. This clearly distinguishes interactive media from other types of media, and in turn allows to potentially prompt a range of emotions that cannot be prompted otherwise: namely, *moral emotions* (Zagal, 2009; Švelch, 2010; Sicart, 2013), such as guilt, or pride, which require the person to feel responsible of their decisions.

Among many others, some examples of digital games that clearly integrate an ethically-relevant dimension in them could be *Papers, please* (Heron and Belford, 2014), *Bury me, my love*, or *Undertale* (Seraphine, 2018), just to name a few. Similarly, some examples of tabletop games that show how players can also get subjectively involved in regards to their ethical dimension are *Train*, or *This War of Mine*, for instance. In order to achieve this sort of subjective involvement in a game there might be no infallible, secret formula; nevertheless, there are a few features that, although maybe not sufficient, can he helpful to open up the path towards making the players feel subjectively invested in the morally-relevant dimension of the fiction.

2.1 Techniques for Moral Gameplay in Digital Games

Making an exhaustive list of game design techniques that could be successfully used to prompt genuine ethical reflection through moral gameplay would surely take more space than can be devoted in this paper, so the focus here will be placed on some of the most common approaches that can be found in games that are usually considered in the analysis of morality systems and / or moral gameplay.

2.1.1 Explicit vs. implicit morality systems

Although it might sound contradictory at first, having a morality system that is explicitly shown to the player is not a technique that prompts, *per se*, genuine ethical reflection on the player. An *explicit morality system* can be understood as the archtypical single, or multi-axes-based system that shows the current state of the PC's moral persona to the player. Typical examples of games featuring some variations of this approach include *Fable* series, *The Elder Scrolls* series, some titles in the *Fallout* series (see (Casas-Roma and Arnedo-Moreno, 2019) for a comprehensive analysis of the different techniques used for morality systems in the series).

There are some issues related to explicitly showing the player what their moral persona is at each moment. One of them is the fact that the player doesn't need to remember and reflect on the moral dimension of the decisions they have made in the past, as the system explicitly keeps track of that. Rising awareness and reflection on ethically-relevant matters requires to foresee and understand the ethical dimension of a reflection without resorting to an explicit, objective account of it that can be checked. Similarly, explicitly showing the PC's moral alignment leads to the morality system becoming another strategeable part of the game that can easily be seen as a stat that have to be tweaked in order to achieve certain in-game rewards. As such, the moral dimension of in-game decisions can end up feeling only as a means to an end in order to tweak such stat --just like any other number-driven stat in the game.

In this regard, it is possible to use implicit morality systems that require the player to understand, remember and anticipate their morally-relevant deeds within the game fiction and without non-diegetic feedback from the game, such as in *Ultima IV*, which require that the player gets genuinely involved in the game's world and it values in order to move forward in it (Hayse, 2010). Other techniques such as the so-called *hidden spectator* (Švelch, 2010), which secretly tracks certain decisions without the player knowing in order to "come back" at the player afterwards, can be used to avoid the effect of the player delegating the weight of their morally-relevant actions unto the game's system. Instead, these techniques require the player to understand, anticipate and remember their actions "outside" of the game's HUD and "inside" the game's world, and therefore can be better suited to genuinely involve the player into the moral dimension of their actions.

2.1.2 Anticipating choices' polarity

Some games, such as the *Mass Effect* trilogy, provide a color code in the dialogue choices offered to the player in order to let them recognize, prior to making a choice, what alignment is supported in that choice. This is useful in order for the player to decide what alignment they want to play, and stick to decisions that are in accordance to it. Nevertheless, by using this technique the player is not required to try to understand and anticipate how each choice could affect the story and the characters in it, as the "good" and the "bad" choices are already highlighted to them.

Similarly as in the case of morality systems, providing explicit clues on the moral polarity of a choice can easily lead to the player delegating their understanding of such choices and their potential outcomes to the feedback provided by the game's HUD. As in the case of morality systems, removing this feedback (which, in this case, would amount to not highlighting the moral polarity of the choices available) would require the player to understand and anticipate, through their own reflections, what outcomes a choice is likely to cause.

2.1.3 Choices that are (or are perceived as) meaningful

Meaningful choices, in this context, refer to choices that have actual consequences within the fictional setting, rather than being simply cosmetic choices that do not really affect the fiction in any relevant way. When players are given a choice in interactive media, these choices must either be, or at least feel meaningful in order for the players to become invested in them. Becuase, if the players' choices do not actually affect the fiction in any relevant way, why care about those choices? Or, alternatively, if no choice is even given, why should players feel that whatever happens to the characters is their responsibility?

The most obvious way of making a choice *be* meaningful is to have it affect the way the story unfolds --that is, to have some sort of branching narrative structure (Heussner et al, 2015). Nevertheless, interactive narratives that *truly* branch into different paths with significant differences and long-lasting consequences, instead of just being cosmetic divergments that ultimately converge into the same end-point (what is sometimes known as a *diamond-shaped structure*), can be rather costly in terms of the amount of writing and resources needed. As a more cost-effective alternative, and in order to avoid having to develop a different path for each and every choice available, choices that significantly affect the path of a narrative can be combined with other choices that, although maybe not being meaningful *per se* in terms of how they affect the overall plot, can *feel* meaningful through the way they are presented and perceived by the player.

Examples of such choices can be what is known as the *illusion of choice* technique (Švelch, 2010). Examples of this technique can be seen in games like *Silent Hill 2*, where at a certain point the player is given the "choice" to either try and save a friendly character from a monster, or to run away and leave the character on their own -- the funny part being that the player cannot possibly defeat that monster, and therefore any attempt to intervene will inevitably result in the death of the player, thus leaving them with the only option to run away and abandon the friendly character. Despite being no possible alternative to doing that, having the player be the one who actually has to "decide" to run away and leave the other character behind, rather than incorporating that as part of the animated sequence, can make the "choice" feel much more meaningful than if the player was just kept as a back-seat driver.

2.1.4 Forming para-social attachments

Attachments, in this context, refer to the ability that some works of fiction (including interactive media like digital and tabletop games, but also present in other forms of non-interactive media like books, movies, etc.) have to make the audience develop a sympathy towards their fictional characters --in other words, to allow for inter-subjective relations to appear between the spectator and the fictional characters in order to make the audience "care" about them. Becuase, otherwise, why would it matter to the players what happens to the fictional characters, if they do not feel a sympathy towards, or feel attached to them?

When thinking about para-social attachments, one usually thinks about attachments that the player may form with the fictional characters inhabitting the game --that is, the non-playable characters, or NPCs. The "shape" of a character can be important when determining whether para-social attachments can be formed with the player. Characters can be considered *flat* when they do not explicitly embody a personality, a belief system, or drives and goals, and be considered *round* otherwise --that is, when the fictional character is shaped to embody a specific personality and particular mental trait (Forster, 1974). When focusing on NPCs, flat characters might feel more generic and impersonal than fully-fledged, round characters, and therefore it might be harder for players to become attached to them. Conversely, when NPCs are shaped as round characters exhibiting their own beliefs, drives, strenghts and weaknesses, developing an empathetic relationship with them may be easier, and therefore players might be more prone to caring about such characters and what happens to them.

2.1.5 Towards genuine moral reflection

By distilling the previous considerations on different techniques that can be applied in the context of moral gameplay, it can be concluded that aiming towards genuine moral reflection in the player might go in the opposite direction of a common principle in game design: feedback. In this sense, the more feedback the player

is given regarding the moral dimension of their choices (at least in terms of non-diegetic feedback, such as in the case of HUD elements, stats, highlighted parts of the game screen, etc), the less the player is required to genuinely and subjectively understand, anticipate and reason about such moral dimension. Of course, a balance is needed, and feedback must sill be given for the player to understand how their actions affect the game; otherwise, the player might end up believing that none of what happens has to do with their choices. This feedback, nevertheless, may be given through diegetic elements, such as the way the enviornment and the NPCs react to what the player do, or even by integrating it into the game's lore, such as in the case of *Ultima IV*.

Aiming for genuine reflection from the player appears, therefore, as a matter of finding the balance between how much is hidden and how much is shown to the player. In other words, genuine involvement requires to find a compromise between how close the game gets to the player, and how close the player is required to get to the game, so to speak. It requires for the designer to play the magician and understand how much is shown and how much is hidden to the player, and wait for the player to play their part in the game and get invested and immersed enough as to reflect on the morally-relevant nuances of the situations they are faced with.

3. An Interactive Narrative for Moral Gameplay

The previous reflections have been used in the design of a prototype of an interactive narrative experience aimed at supporting the learning of ethics in students and professionals. In particular, this prototype is directed towards information technologies (IT) students, as the current and future importance of digital technologies in virtually every layer of society already has the capacity to affect individuals, social groups and the whole society in profound ethically-relevant ways. The main motivations, theoretical framework and design decisions behind the prototype, which is currently being implemented using the *Twine*[1] editor for interactive narratives, are explained and justified in (Casas-Roma et al, 2022), but can be summarized in the following points:

- Acquiring ethical competences and skills is of paramount importance in order to tackle current and future challenges that professionals face and will have to face.
- Ethical thinking, therefore, should be part of the IT professionals' (as well as other kind of professionals, of course) development mindset and should be present in all stages of their professional practice.
- Interactive experiences could be used to support traditional methods in teaching and learning ethics as a skill, and can provide the subjective experience that other methods, such as purely descriptive and normative approaches, cannot offer.
- Following this, the aim of this interactive narrative is not to teach about particular ethical norms, but rather to present the students with choices that might not have a clearly good or bad solution (in line with what (Sicart, 2013) calls "wicked problems". In this sense, the aim is to contribute to the integration ethical thinking as part of the default mindset of the students by aiming to prompt genuine ethical reflection during the interactive narrative.

With the previous considerations on moral gameplay design techniques and the structural decisions made in the design of the interactive narrative prototype, the following sections present some examples to show how these considerations have been translated into the content of the interactive narrative.

3.1 Forming Attachments with the Characters

The prototype for the interactive narrative features four different characters that intervene at different points in the plot: Claire, Mark, Alex and Peter. Out of these four, two characters (Claire and Peter) have a closer relationship with the player character (PC), and therefore the decisions made by the player have a greater effect on the way these relationships evolve in the narrative. This is tracked by using an (implicit) *approval system*. Aside from their particular role each character plays in the fictional plot, each one of the four characters has been included into the interactive narrative to fulfill certain "functions" regarding the player, such as impersonating certain pressure points in some decisions, or exposing the player through different points of view by using these characters' voices --instead of using an impersonal narrator's voice[2]. In a nutshell, the characters' roles and functions are:

[1] https://twinery.org/

[2] Among other reasons, presenting these reflections through fictional characters, rather than through the passive voice of a narrator, has been motivated to avoid the feeling that the narrator's voice is omniscient, or that is has some "privileged" view of the state of affairs that strengthens any reflection uttered from that point of view. Instead, conveying such considerations through the voice of fictional characters allows to clearly relate those considerations to subjective points of view that depend on the specific beliefs and goals of such characters and that, furthermore, do not need to be true.

- Claire is a coworker in the PC's team who always advocates for choices that are ethically-correct, from her point of view and in regards to the ethical principles that appear in this interactive narrative. This means, however, that their advice might put in jeopardy other needs that might also need to be balanced during the game, such as the resources.
- Mark is also a coworker in the PC's team that somewhat plays the counterpart of Claire and prioritizes choices that are more favorable towards the team's productivity goals (and thus which positively affect the resources devoted to it), but which might not always take into consideration the ethical principles that are either upheld, or disregarded by such choice.
- Alex is the leader of a rival team which can compete with the PC's team for resources and recognition. As such, Alex would amount to a mild version of the story's villain. In this sense, Alex's function (besides his involvement in the narrative's plot) is to add pressure to the PC's decisions and outcomes.
- Peter is a representative of the management team and therefore impersonates the "higher power" of the company itself, having the power to decide over the PC's team and its resources. In this sense, and even if Peter's interactions are kept to a minimum, they represent higher order requirements that should be taken into account by the PC --and which, if they are disregarded, may lead to detrimental outcomes for the PC and their team.

3.2 Meaningful Decisions Through Variables and Choices

The overall structure of the interactive narrative is formed by a combination of *branches* and *gates*, together with the use of *global variables* to affect later sections of the narrative through previous choices (Casas-Roma et al, 2022). Choices available in this prototype have been designed to avoid providing clearly "good", or "better", and clearly "bad", or "worse" options; the reason behind this is because this prototype is not designed to support the teaching of "content" related to ethical principles, but rather to foster ethical reflection as part of the players' mindset at each and every decision they face. In the sense, and after drafing the overall narrative's plot and main events, a structure was created to keep track of how each and every possible choice within the narrative would affect each variable.

The initial state of the narrative features the following variables' values:

- *Ethical principles*: The player character starts the narrative with a "clean slate", with regards to their alignment with ethical principles (such as *honesty*, *integrity*, *user consent*, etc). As no decision has been made yet, all variables related to ethical principles are initiated at 0 (meaning that they have neither been upheld, nor disregarded).
- *Character approvals*: The fictional setting establishes the player as being the leader of a team in an already established company where both the player, as well as the rest of the fictional characters, have been already working for some time. In this sense, the player character is not unknown to the rest of the characters, and therefore the relationships are already established in a certain way[3]. The initial relationships are as follows:
- *Claire*: The initial relation with the player character is a positive relationship based on professional respect, trust and companionship. This is expressed as starting with a positive +1 approval rating (within a range of [-3, +3] ranging from *hatred* to *personal friendship*).
- *Mark*: Similar to Claire, the initial relationship with the character is based on professional respect, trust and companionship. Again, this is expressed as starting with a positive +1 approval rating.
- *Resources*: Even though it was initially planned to allow resources to both increase and decrease depending on various choices, in the end, and mainly due to the limited scope and length of the present prototype, resources start at a fixed positive amount of +2 and can either be maintained, or decreased, but never increased[4], thus ranging between [0, +2].

Providing an explanation of the context and ways in which every choice would affect each variable, even if kept brief, would not be feasable in this work for reasons of space. Nevertheless, a summary of the effects that the choices currently implemented within the interactive narrative have over the variables can be seen in Table 1.

[3] Note that, in the cases of the characters named Alex and Peter, the relationship they have with the character throughout the narrative is not explicitly tracked. Decisions made by the player during the narrative only affect those characters in cosmetic ways (i.e.: the way they react, their dialogue, etc).

[4] Undoubtedly, a longer narrative might benefit from the chance of making certain decisions that, although maybe at the expense of sacrificing some other variables, allow to increase the in-game resources in order to either gain some in-game benefits, or to gain some margin to allow for the loss of resources in other future decisions. Nevertheless, and because the scope of the present prototype is limited, this way of handling the resource variable is more convenient for practical terms.

Note how choices' outcomes have been intentionally curated to affect different variables and to try and balance their overall effect in order to avoid presenting a clearly beneficial path (where all, or most of the constrains are consistently satisfied), as well as to avoid a clearly worse path.

Table 1: Summary of the main choices and effects on the variables

	Claire's approval	Mark's approval	Resources	Ethical principles
Session 2-1	+1 / +0 / -1	-1 / +0 / +1	-	-
Session 2-2	-	-	-	+ / -
Session 3-1	+1 / -1	-	-1 / +0	+ / -
Session 3-2	-	-	-1 / +0	+ / -
Session 4-1	+1 / -1	-1 / +1	-	+ / -
Session 4-2	-	+1 / -1	+0 / -1	- / +

Considering the initial state of the variables, as well as the potential choices within the prototype, the possible "end game" states, with relation to the existing variables, are as follows:

- *Ethical principles*: Once the epilogue has finished, the last end-game screen will show the player the ethical principles that have been involved as part of their decisions during the narrative, and they will be presented with a screen summarizing which principles they have upheld, and which they have disregarded. This is where the in-game ethical principles can be related to the professional principles from which they were distilled, such as the ACM Code of Ethics[5].
- *Character approvals*: Aside from the way this rating affects the dialogue and the characters' reactions during the development of the narrative, the way the characters intervene in the epilogue will be determined by this.
- *Resources*: The range of this variable at an end-game state is within [0, +2]. The value of this variable might trigger one further decision for the player at the epilogue of the game:
- If Resources = +2, the player has managed to keep the team within the required productivity rate for the company, and no further decision is required.
- If Resources = +1, the player has not been able to keep the team within the expected productivity margins, and some restructuration is needed. As the leader of the team, the player is asked to fire either Claire, or Mark from the company.
- If Resources = 0, the player has consistently made decisions that had compromised the team's expected productivity margins, and management sees the team more as a liability than an asset at that moment. The PC is reassigned to Alex's team, and both Claire and Mark are fired.

An example of an in-game choice can be seen in Figure 1, which shows an excerpt in the Twine editor. At that point in the narrative, the PC is sharing their concerns about the possibility of the software showing bias with their two colleagues, Claire and Mark. After having suggested a possible way of moving forward, and having let Claire and Mark express their opinions regarding what to do, the player has to decide how they would like to distribute the tasks among three possible choices.

Another example of a choice can be seen in Figure 2, which shows a fragment of the scene where such choice is presented in a web browser when testing it directly from the Twine editor. Choices available to the player are shown as interactable parts of text in blue color; furthermore, an *inner monologue event* (see next section) has been already activated and corresponds to the text in italics in the third line of the paragraph.

[5] https://www.acm.org/code-of-ethics

```
Besides, I don't like to talk badly about anyone, but... who claimed OUR
software is biased? Alex. How convenient would it be for him and his team
if that was true, right...? Or even if it wasn't true, but we wasted a
whole week of our time behind that, that'd be very convenient for him.
Look, what I mean is that we do NOT know if our software is biased, yet we
DO know we have been trusted with a rather complex project, which we are
supposed to deliver all good and running soon, and for which we need all
the time we can get... and you know this, boss."

Claire is about to answer and opens her mouth, but only a sigh comes out of
it. Mark looks at you. "So, what is it going to be, boss?"

[[Stand by your decision: running the tests is a priority. -> PREdevote-
CHOICE-devote-full-team]]

[[Reconsider and split the team between the tests and the current project.
-> PREdevote-CHOICE-split-team]]

[[Reconsider and keep the full team devoted to the forthcoming project. ->
PREdevote-CHOICE-no-reassign]]
```

Figure 1: Fragment of a choice in the Twine editor.

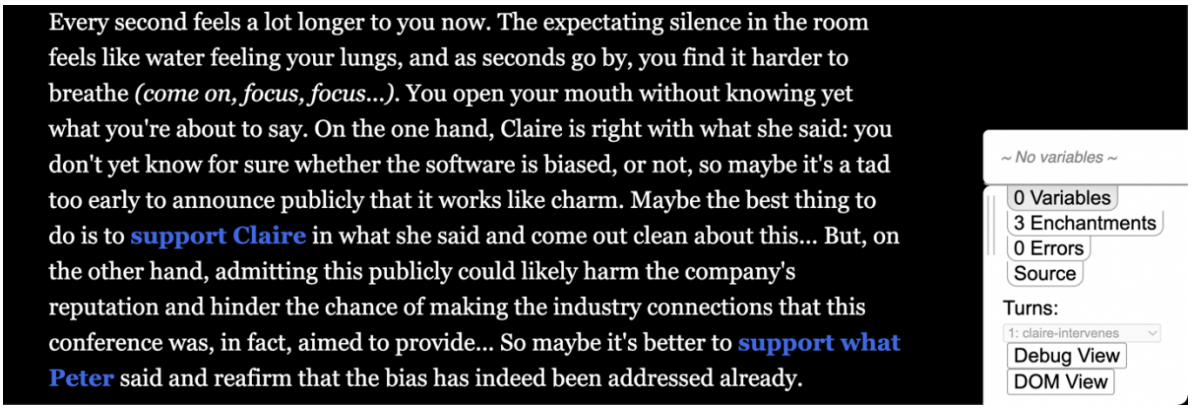


Figure 2: Choice shown in the web browser while testing the prototype.

3.3 Prompting Reflection through Spaces, Implicit Systems and Inner Monologue Events

Spaces of reflection are created by dividing the narrative into different sessions, each one related to a specific key event within the plot, and separating these sessions by a certain timespan in order to create a space for players to potentially reflect on their choices and anticipate on the potential consequences (Casas-Roma et al, 2022). This technique, together with the fact that variables are tracked implicitly and that no non-diegetic explicit feedback is given regarding the value of such variables, aims to prompt for the genuine reflection and involvement of the player in their decisions.

Additionally, there is another technique that is used in the development of this narrative to further enhance subjective reflection and immersion to the players: the inclusion of *inner monologue events*, which allow the player to interact with certain parts of the text in order to expand them with brief bits of text representing the PC's thoughts about that. An example of such event is as follows; the interactive event is marked as underlined text here, and the two bullet points show that part of the text before, and after interacting with the event:

- (...) "I want to thank you for this *great* presentation, in the first place..." You struggle to keep smiling as you listen to the rest of his question. (...)
- (...) "I want to thank you for this *great* presentation, in the first place..." You struggle to keep smiling *(why did he put so much emphasis on the "great" part?)* as you listen to the rest of his question. (...)

3.4 Towards an evaluation

The aim that this interactive narrative has, with respect to supporting the learning of ethical skills and competences, presents some challenges in the way it could be evaluated. There exist some examples of interactive narratives that have been created with the purpose of teaching research ethics (particularly in the

research misconduct, as in *The Lab*[6]. In those cases, the players who engage in the narrative are exposed to a series of good practices, principles and ways of carrying out hypothetical research activities that are aligned with ethically-desirable practices; as such, there is a *content* (be it in the form of good practices, or particular rules and principles) that can be learned, asked about and therefore assessed. In the case of the present interactive narrative, nevertheless, the goal is different, and probably more challenging to evaluate. The aim, in this case, is to prompt ethical awareness and reflection as part of the students' mindset when tackling problems related to their professional activities. Due to this, there is no specific "content", or specific skill, that can be easily accounted for and therefore evaluated before and after engaging with the prototype.

Approaches to evaluate and account for learning not solely based on specific knowledge or skills, such as the WeValue Methodology[7] for values-based learning, have been proposed. In those cases, evaluations often involve qualitative measures, subjective reflection and individual participation from students and teachers alike. This is, precisely, because what is meant to be taught and evaluated falls outside the scope of competences that can be easily demonstrated and measured via traditional assessment methods. In this sense, the approach followed in value-based learning could be a promising avenue towards the design of an evaluation method for the interactive narrative proposed in the present work, and will definitely be considered as the starting point once the prototype is finished and an initial evaluation process is designed.

4. Conclusions and Future Work

This paper discusses some game design techniques that can be used in the design of moral gameplay and towards aiming to prompt genuine moral reflection in the players. This discussion of existing techniques suggests that, in order to achieve genuine involvement for tha part of the player, a balance needs to be found between providing explicit feedback regarding the ethically-relevant elements in the game, and the requirement for the player to subjectively engage in the game's fiction. The more the game explicitly aids the player in their moral decision-making and the tracking of their moral persona, the less the player needs to understand, reflect on and anticipate the moral dimension of their choices. The insights gained from this discussion is then used in the design and development of a prototype for an interactive narrative aimed to be used as supporting material to teach ethics as a skill, and some examples belonging to this interactive narrative are presented. Lastly, an initial consideration regarding how this kind of learning could be evaluated is suggested as a first step towards en evaluation method to test the effectiveness of this prototype.

A clear line of future work, once the prototype is ready, is to run a few preliminary tests and get some qualitative feedback regarding the content, structure and engagement of the interactive narrative in order to iterate and improve any identified shortcomings. These preliminary tests can be run among fellow educators and game developers to assess both their teaching potential, as well as potential improvements in terms of narrative design. Once the prototype has been refined, designing an evaluation procedure and running larger scale tests among students would be the next natural step. The design of this evaluation procedure should be carefully tailored in order to ensure that it measures what this interactive narrative is meant to provide support to, rather than what is usually measured in traditional learning materials: namely, the evaluation should be shaped in order to measure whether there is an increased predisposition in integrating ethical thinking as part of the default mindset of the students.

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Eco Tetris: A Serious game on Sustainability

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Abstract: Recycling has grown to be extremely relevant for the maintenance of our planet, but also for our well-being. Sustainability is a key issue in modern societies, relying on intergenerational care and education to promote recycling habits and social responsibility. Raising awareness towards recycling and healthy environmental habits, and motivating people to become more responsible about sustainability and the environment might be achieved through a game, designed to be simple and intuitive and to enhance the learning process. Eco Tetris is a game, designed to teach about the importance of recycling. Based on the well-known Tetris game, Eco Tetris builds upon this by adding card collecting mechanics and integrating the game with the real world via geo-referencing, beacons, and augmented reality experiences. The main goal of this game is to raise awareness and make the players more conscious of their environmental decisions and habits, while also being entertained. Our primary focus is the older generation, for whom the game is kept simple, in terms of both usability and design. Eco Tetris is a game whose main concern is to transmit knowledge on how to recycle and its importance for our planet. In this game, players are challenged to place the garbage in the right recycling bin. The mechanic is virtually the same as when recycling. Our goal is to imbue the player with recycling habits. The core gameplay loop will have the player doing the sorting exercise – separating garbage in-game, mentally associating it to its right colors. The bridge between the in-game and real-world is achieved via geo-reference modules and beacons. When visiting an eco-point, the player will have access to additional content, like an augmented reality experience, that provides positive reinforcement and knowledge about players' actions and the environment in general. We expect this game to promote ecological responsibility and a major view of one's role in the recycling process. The game is developed towards the enhancement of decision-making, memory skills, awareness, responsibility, and learning of its players.

Keywords: Serious game; Sustainability; Learning process; Usability; Beacons

1. Introduction

In the long term, a limited climate impact and sustainable development are of extreme importance for the planet. To better achieve it, the increase of a sense of social and global responsibility is a major concern of public policies and political goals.

When thinking of sustainable development, there should be a consideration for the maintenance of a green environment, better quality of life, and wellbeing. Thus, sustainability can be seen as a combination of environment preservation, protection, and stability. It also relies on a series of practices, habits, and behaviors, both individually and collectively, to reduce and minimize the destruction of our ecosystems (Koren, 2017).

Pro-environmental practices, habits, and behaviors must be continuous and enduring. In the context of environmental sustainability, the focus has shifted to understanding individual habits, such as recycling (Thomas & Sharp, 2013).

Recycling can be seen as an approach toward reducing waste disposal and limiting the climate change impact, while also being an approach to environmental preservation. The difference between recyclers and non-recyclers can be found in their beliefs, their social norms, their access to infrastructures and services of recycling, and their awareness and knowledge or lack of it (Thomas & Sharp, 2013).

For this reason, understanding information, knowledge, and education as key drivers of change, allows for a more deliberated solution. Motivating recycling is now more than just the government's responsibility. The normalization and increase of recycling habits must now be a concern of every individual, that understands the relationship between recycling and other important pro-environmental practices toward sustainable development (Thomas & Sharp, 2013).

Thus, our proposal is a serious game that raises awareness towards healthy environmental habits such as recycling, that aims to encourage people to become more conscious and responsible. Eco Tetris builds upon a

well-known game (Tetris), but, besides its entertainment purposes, it also focuses on educating the older generation about the need to protect and maintain the health of our planet.

Since the aim is to imbue the player with recycling habits, the core gameplay loop will have the player doing the sorting exercise. This means that the player will need to separate the garbage in-game and associate it with its recycling bins right colors. Color-coding systems are an important provider for interpreting encoded messages. When relying on text or audio is not possible, visual features can help people to access important information (Schloss, Lessard, Walmsley, & Foley, 2018). This is also an important part of the learning process since it creates a relationship between the virtual experience and the real-life world.

By raising awareness among the older generation towards recycling and sustainable development, it is expected that pro-environmental practices and intergenerational care increase at a micro level, fighting the concern of different countries and organizations of a possible irreversible climate emergency.

2. Recycling: an approach towards social responsibility and sustainability

Sustainability is a key issue in modern society, that has grown to be a waste society (Feo & De Gisi, 2010).

> *Waste could be considered the final product of a special production chain: wealth, consumption, waste. The wealthier the society, the greater the consumption; the greater the consumption, the more waste produced I*

As such, "under modern waste management systems, a high priority has been placed on recycling of waste materials" (Salhofer & Isaac, 2002). However, in attempts to increase recycling, difficulties have arisen.

> *Globally, coming to terms with excessive waste pollution is critical for the aim of reaching the goals of sustainable resource management. This implies a need to increase recycling by individuals. However, this is easier said than done. Recycling at the household level is associated with costs (e.g., it is time-consuming) that incentivize individuals to avoid cooperation, i.e., adopting a free-rider behavior rather than choosing to recycle* (Harring, Jagers, & Nilsson, 2019).

The inherent goal of recycling is to limit the impact of waste disposal. When choosing to adopt pro-environmental and sustainable behaviors such as recycling, the maintenance, and health of our planet are assured, as also our well-being. Misinformation or lack of it can inhibit these habits, making awareness necessary. By adopting an educational-based approach, it is possible to increase the engagement in the recycling process, the frequency of participation, and the number of recycled materials (Lane & Wagner, 2013).

But, when comparing access to information and pro-environmental habits, we notice that not always do people make their decisions based on knowledge and awareness (Feo & De Gisi, 2010). This relates to a non-significant relation between sustainable awareness and actual behavior (Cogut, Webster, Marans, & Callewaert, 2019).

> *In terms of creating awareness for environmental sustainability, two perspectives were identified concerning behavioral change. The first perspective assumes that changes in behavior are brought about by increasing public knowledge through raising awareness regarding an issue and by fostering an appropriate attitude. The second perspective proposes that individuals systematically review their choices and then act in their economic self-interest without the need to have enough knowledge and awareness in the first place* (Hamid, Ijab, Sulaiman, Anwar, & Norman, 2017).

Thus, these pro-environmental attitudes, habits, or behaviors can be enhanced by engagement and awareness (Cogut, Webster, Marans, & Callewaert, 2019). Also, motivation can play an important role in increasing recycling habits, as well as technical infrastructure and orientation (Salhofer & Isaac, 2002).

> *[These are] the following requirements for environmentally oriented behavior: (1) There should be sufficient knowledge of the ecological context (the cognitive component) and a positive inclination towards ecological values. (2) The infrastructural prerequisites needed for environmentally oriented behavior (e.g., collection containers) must be available. (3) Environmentally friendly behavior must lead to positive results; therefore, incentives (possibly economic incentives) could be given* (Salhofer & Isaac, 2002).

Adopting these pro-environmental habits, such as recycling, sustainable development, and the maintenance of our planet is made easier. Sustainability can be seen as stability, integrity and well-being, and health of humanity.

To promote this sustainability agenda and an enduring state, an integrated and proactive approach must be held individually and collectively (Ben-Eli, 2018).

> *Viewing sustainability as a system state—the result of the interaction of identifiable, specific variables—and anchoring the concept in the interaction of population and carrying capacity, leads to a more rigorous definition, [as follows]: (…) A dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible adverse effects on the carrying capacity of the environment upon which it depends* (Ben-Eli, 2018).

But, at this moment, the behavior of humanity is unsustainable, since people do not always participate in recycling even when infrastructures are provided (Thomas & Sharp, 2013).

> *As current consumer-driven behaviors and culture are inherently unsustainable, working toward changing behavior at the individual level is an essential component of being environmentally responsible citizens and working toward promoting a culture of sustainability. A culture of sustainability has been defined as: [. . .] a culture in which individuals are aware of major environmental (and social/economic) challenges, are behaving in sustainable ways, and are committed to a sustainable lifestyle for both the present and future* (Cogut, Webster, Marans, & Callewaert, 2019).

Following the Millennium Development Goals, the 2030 Agenda for Sustainable Development of the United Nations highlights the importance of environmental sustainability, since it considers that our planet now faces an environmental and climate emergency (Arora & Mishra, 2019). For those reasons, solutions on a micro level such as raising awareness through an educative and serious game can support the agenda toward environmental sustainability (Arora & Mishra, 2019).

2.1 Serious games and sustainability

A mindset towards sustainability, pro-environmental habits and social responsibility relies on numerous and different approaches, such as serious games. These serious games, that intend to be educational, are an important tool for improving recycling habits, given that "While public awareness of climate change has grown over the years, many people still have misconceptions regarding effective individual environmental action" (Wang, et al., 2021).

> *Goals of serious games on sustainability could be summarized in (a) making players aware of the challenges associated with sustainability, (b) providing knowledge and understanding with the issue of sustainability, and (c) encouraging players to take actions and develop solutions that are environmental and socioeconomic balanced* (Ouariachi, et al., 2018).

Considering the high potential digital games have on improving knowledge, literature identified the importance of a "sustainability mindset which enables individuals to engage in sustainable behaviours" (Fabricatore & López, 2011). Characteristics such as "domain-specific knowledge", "reflective and critical thinking", "systems thinking", "sense of belonging to a living system" and "emotional commitment to sustainability" are found to be necessary to make people more aware and involved, more responsible and understanding, and more active and cooperative (Fabricatore & López, 2011). This is how digital games can help to educate on sustainability.

For instance, the creators of the serious game PEAR developed a game that has proven to improve "participants' knowledge on sustainability and climate-change-related issues". Their findings also demonstrate that this knowledge improvement result in pro-environmental attitudes. By using a game that is engaging, educational and immersive, behaviours change (Wang, et al., 2021).

In fact, the numbers are increasing. Over the last years, several digital games were developed thinking on sustainability. Games such as Keep Cool ("where players represent groups of countries that negotiate economic growth and climate change mitigation"), Climate Mission 3D ("where players learn how to reduce their carbon footprint as they play a series of mini-games") and We Energy Game ("a serious game that aims to create awareness on the challenges in the provision of affordable energy from renewable sources for an entire town or city") are found to be engaging and educational in terms of both sustainability and pro-environmental habits (Ouariachi, et al., 2018).

3. Methodology

Eco Tetris is a serious game on sustainability, social responsibility, and education. The project aims to develop an innovative concept for recycling, along with new technologies and automation strategies. The Eco Tetris methodology and the outcomes of the project will enhance knowledge and awareness, concern for the environment, and intergenerational care.

3.1 Concept

Eco Tetris is a game designed to teach about the importance of recycling. Eco Tetris is based on and built upon the well-known Tetris game, by adding card collecting mechanics and integrating the game with the real world via geo-referencing, beacons, and augmented reality experiences.

Eco Tetris aims to respond to the growing importance of sustainability, the planet's maintenance, and individuals' well-being. The idea is to raise awareness towards recycling and good environmental habits, by motivating people to become more responsible about ecology. The game should be simple and intuitive, created to consider older audiences.

The main goal of Eco Tetris is to spread awareness and knowledge about recycling and better environmental habits. With features such as multiplayer, card collecting, and using beacons, we hope to make our players more aware and conscious of their environmental decisions, while also being entertained. Our primary focus is the senior generation, for whom we plan to keep things simple, in terms of both usability and design.

We expect to raise the player's awareness of their choices and actions on a daily basis and realize their impact on the environment, by creating a better sense of responsibility and motivating more families into creating good recycling habits. The aim is to promote intergenerational care, education, and well-being, by imbuing the older player with recycling habits. So, in our game, players are challenged to virtually do the sorting exercise (separate garbage in-game), which creates a bridge between the in-game and the real-world recycling, that is achieved via geo-reference modules and beacons.

The game is also important to the development of different competencies and skills, such as decision making, memory skills, drive for results, and education on how to recycle. This acquired knowledge of the players will be evaluated by the in-game score and their position on the overall ranking. By tracking beacon usage metrics and cross-referencing with player data, the "conversion rate" can be obtained, providing insight into how many players are led to recycling more after playing the game.

The approach to this project is to launch the game on the app stores. In an initial phase, we plan to consider only a small area, where a small number of beacons can be spread in recycling points. This would serve as an initial test of our concept. Since it is meant to be tested on a local scale, it also means that it will be easier to collect additional information and feedback early on from players. The next steps would be to secure a connection with distributors or even proper institutions, to finance and distribute the beacons across recycling points. Notwithstanding, there needs to be a heavy investment in an advertisement – we would aim to target TV ads and influential people among the older generations to spread the idea and use of our game. Finally, we should secure a partnership with a company that will control, monitor, and maintain the beacons, replacing those that need to be replaced and adding more, covering wider and wider ranges of recycling points. Another option to consider is a partnership with a company that is responsible for waste collection and processing like Lipor, they could promote this game as a plan to educate people on the process of recycling.

3.2 Objectives

The Eco Tetris game aims to promote better recycling habits to reduce the climate impact, raise awareness towards good environmental decisions, and enhance sustainability and global responsibility. This project is focused on creating a digital tool and digital content to be available on different platforms and to every player. By focusing on the older generations, the game relies on its easiness, inclusiveness, and intuitiveness.

For that purpose, Eco Tetris will pursue a set of specific objectives, such as enhancing intergenerational care, education, and knowledge about ecology. Creating a better sense of global responsibility will contribute to promoting sustainability and well-being. In concrete, this game will pursue the following specific objectives:

- Increase recycling and environmental habits;

- Enhance intergenerational care, by motivating people to do recycling;
- Reduce waste disposal and limit climate change impact on the maintenance of planet Earth;
- Promote knowledge and education for older generations towards social responsibility and sustainability;
- Create a tool that allows raising awareness following the 2030 Agenda for Sustainable Development of the United Nations.

By creating and implementing Eco Tetris it is possible to develop a better sense of social and global responsibility towards sustainability among the older generations, and in a near future, we hope to do the same among younger generations, to educate them with their first recycling habits.

4. Game design and architecture

At Eco Tetris game architecture it was conceived a built-in ambiance and environment referring to a setting that was created within the game. It is how the user experiences the recycling habits with a realistic virtual background making the interaction for the player more realistic.

4.1 Software architecture

There is a representation of four different layers and each of their components Figure 1.

The Presentation Layer is responsible for handling all the user interface logic, allowing the user to effectively interact with the system. The UI_Controllers component acts as a bridge between the first and the second layer, allowing the data communication between them.

The Business Application Layer represents the core of the application. Each component in this layer provides an interface so that other components can make use of it, such as the UI_Controllers mentioned before.

The Persistence Layer provides simplified access to the database's records, such as performing CRUD operations. This way, we can summarize these database calls from the Business Application Layer, making the system more compact and modular.

Finally, we have the Database Layer that contains a database server that is responsible for all the application's data storage and persistence, which the previous layer communicates with, to fetch data for instance.

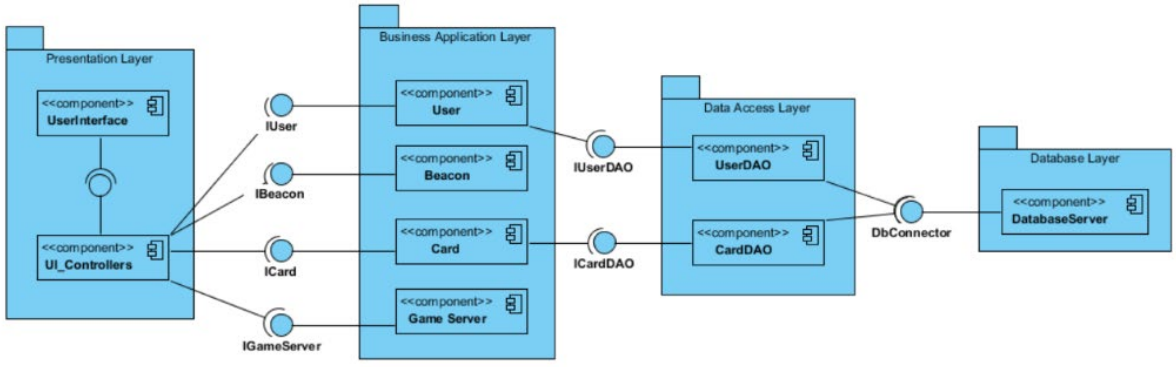


Figure 1: Software Architecture Diagram

It is also important to mention the hardware systems involved in the application Figure 2. This way, the main intersections of the application are the end user's device which is running the mobile application, the server that contains the application logistics and communicates with the app via HTTPS, and the server storage. The following image represents a Deployment diagram, modeling the physical aspects of the proposed system.

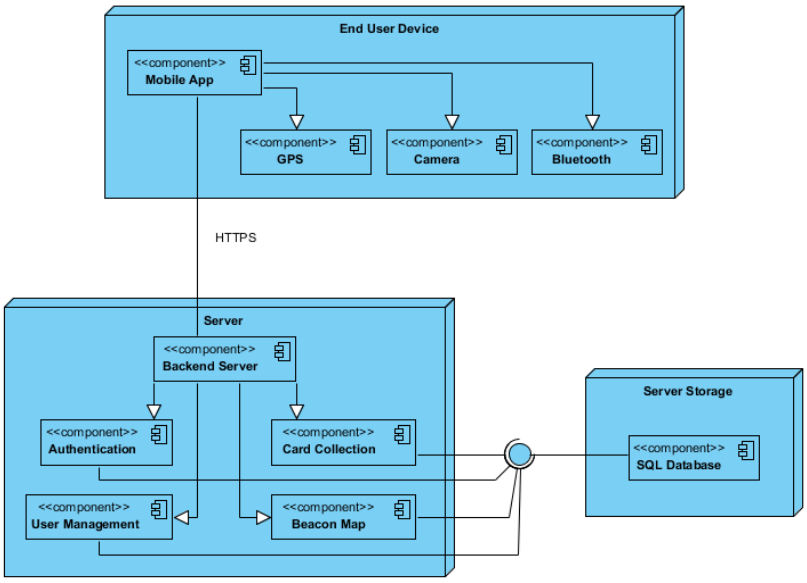


Figure 2: Software Deployment Diagram

4.2 Gameplay

The Eco Tetris game was designed and developed to be intuitive and educational. The following images intend to demonstrate and describe the gameplay and the features of this application.

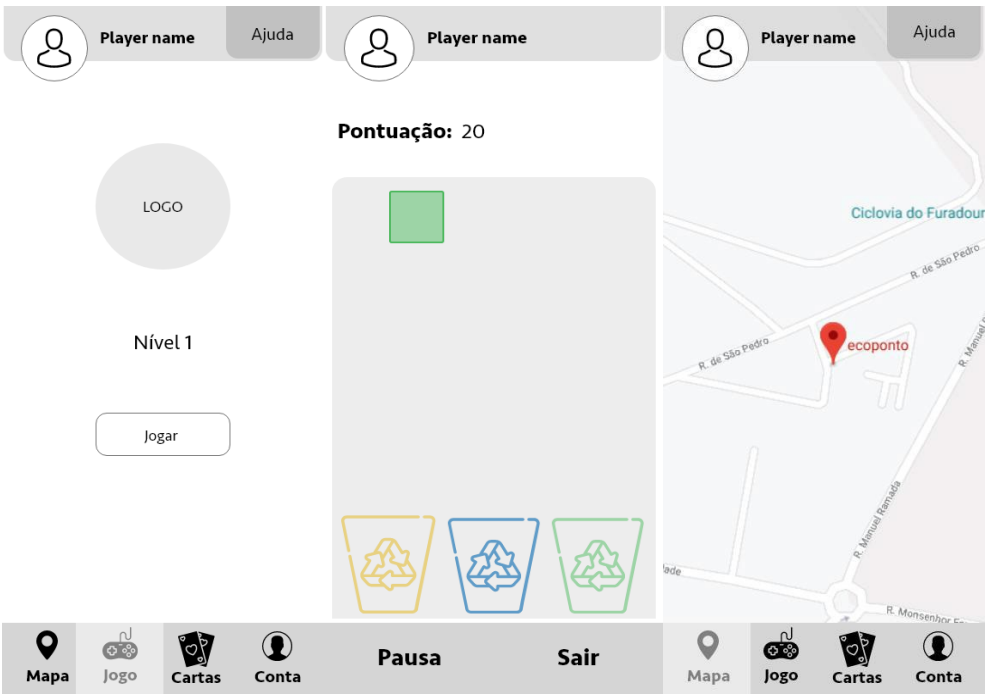


Figure 3: Gameplay

The first screen refers to the application's main menu, where it is possible to access the settings, access explanations of how the application works, start a game, view the card collection and access the map. The second screen refers to the game itself that is meant to teach how to recycle. The upper left corner will contain the user point information. The bar at the bottom of the screen allows exiting the game or pause it. Finally, the last screen is where the user can check where the nearest ecopoints are and actually contribute towards a more sustainable environment.

4.3 Game flow adjustment

Eco Tetris is designed in a way that difficulty can be scalable, to always keep the player within the "flow zone", and not too challenged or bored. The game uses DDA (Dynamic Difficulty Adjustment) in order to regulate this. The DDA allows for the game to automatically adjust its difficulty to the player's performance throughout the gameplay (Oostendorp, et al., 2014).

Thus, the game controls the number of "hits" (correctly placed pieces) and "misses" (incorrectly places pieces). If the player is getting a considerable successful number of correctly placed pieces, it is safe to assume the game is not being challenging enough, and there is a need to scale the difficulty – this will be done by increasing the sleep of falling blocks (gradually, so that it can be nearly imperceptible), and by spawning randomly blocking pieces that will force the player to skillfully navigate around them. The reverse is also true; should the player begin to place many incorrect pieces, these elements that increase difficulty disappear, and the falling speed is reduced.

5. Evaluation and Quality Scenario Control

To assess the Eco Tetris game development and its quality control, we chose to use the Quantitative Evaluation Framework (QEF), which aggregates a set of dimensions, factors, and requirements. We've determined that the focus of this methodology would be functionality, adaptability, and usability (Table 1). To better assure that the game meets its evaluation criteria, the product was assessed during its development using the QEF framework, to have a clear view of its quality. The quality of the game, assessed by this framework, legitimates the system's performance.

Table I: Quantitative Evaluation Framework (QEF)

Dimension	Factor	Requirement
Functionality	Player Interaction	Control falling piece
		The clear line of pieces if in the correct order
		Player gains score points each time a piece is placed on the map
		Columns are associated with a type of recycling bin (green, yellow, blue)
		Pieces have a different color depending on trash type (green, yellow, blue)
		The player passes level if he reaches a certain score
		The player loses 3 times in a row, the level is decreased, power-up awarded
		Get power-ups
		Show player scoreboard
		Higher difficulty means increasing the block's falling speed or more columns
		Background can have different appearances
		Some levels have obstacles on the map
	Multiplayer	Play local multiplayer in turns
		See the score and who won
		Previous multiplayer scores are stored
	Collection	See card collection and information
		Get a card from beacon
		See the map with the location of the beacons
		Create a player's card
	Profile	Create profile
		Account login
		Country flag depending on user location
		The player can customize his avatar
Adaptability	Versatility	Applications are shown in their environments in a native way
		The application adjusts to screen resolution
	Gameplay	Game difficulty is adequate and adjusted
	Maintenance	The application's sensitive data is encrypted
		The server must be scalable
		Players can download DLCs with more avatars
		The game is appropriate for older people
Usability	Menu Navigation	The product has a good structure and allows users to access content in an intuitive way to the main functions
		Unallowed user actions must present a clear warning/error message
	Learning	The player learns which type of trash should be placed in each type of recycling bin
		The player learns about the location of recycling bins

Dimension	Factor	Requirement
	Game	Important player actions have feedback to inform the player
		Augmented reality
	Support	Player data is protected from unauthorized access
		The game is stable and executes systematically without failures
		The game is multiplatform
		The game has multiplayer
		The game is closed source
	Content Quality	The texts are well written, and all the sentences make perfect sense
		All the messages are easy to understand
		All messages should not contain racist, xenophobic, or antisemitic content
		All content is related to the game
		All the text has the appropriate font size for older people

The team used QEF framework to evaluate the educational software quality based on the standard of reference ISO 9126 and SCORM. The system quality is in the inverse proportion of the distance between the Ideal System and the Real System. The closer the Real System is to the Ideal, the higher the quality percentage will be attributed to the real one.

For this, all the requirements were listed, metrics for their measurement defined, and weights for the final grading were attributed to them. Some of the requirements' fulfillment is measured through quality assurance tests, and for the requirements related to the user experience and interaction, surveys are performed.

5.1 Eco Tetris: functionality, adaptability, and usability

The functionality of the game consists of different evaluation criteria that are the core of the product's function. This dimension was divided into four factors such as player interaction, multiplayer, collection, and profile, and each one of them is composed of several requirements.

The adaptability of the game consists of its capacity to adapt to new conditions and features, all players, and all platforms, by making the game more inclusive and scalable. This dimension was divided into three factors such as versatility, gameplay, and maintenance, and each one of them aggregates different requirements to ensure the good performance of the game.

The usability of the game consists of its effectiveness, which relies on the conveying of the correct information and the fulfillment of its purpose- teaching about recycling. This dimension was divided into five factors such as menu navigation, learning, game, support, and content quality.

6. Conclusions

Raising awareness towards recycling and good environmental habits can be of extreme importance to the maintenance of our planet, our well-being, and the sustainability of the environment. Motivating people to become more conscious and proactive can be achieved by different approaches, namely through a serious game. Games can be a great tool for education and enhance the learning process. In the case of Eco Tetris, useful for every age, it is possible to watch the increase of knowledge of the older generation through regular contact with technology.

But not only the older generation can benefit from this tool. Should the development of this project continue, it would be important to further test the existing features and maybe even add new ones. It would be interesting to deploy and publish the software to a wider audience and establish a partnership with companies in other to deploy beacons in all the recycling stations and eco points, allowing for an extended user test and greater feedback to add new features and improve existing ones. Furthermore, the target audience can also be expanded, and the game could turn out to be of greater use in the classroom, to teach younger generations their first recycling habits.

In the end, the Eco Tetris serious game aims to enhance intergenerational care, social responsibility, sustainability, and better planet development. With that in mind, we can expect that the Eco Tetris serious game generates an innovative approach towards sustainability, within the features of education and learning through technological tools.

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Room2Educ8: A Conceptual Framework for Designing Educational Escape Rooms

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Abstract: Despite being a relatively new concept, escape rooms are used in academia as learning and collaborative tools. Research findings have established that educational escape rooms (EERs) can create immersion as they combine the strengths of storytelling and gameplay, therefore eliciting high motivation and engagement and so promoting successful learning. Yet evidence demonstrates that there is little consistency in the approaches adopted in this emerging field. A major obstacle faced by educators is the lack of practical design frameworks for EERs. To address this, we propose Room2Educ8, a user-centred conceptual framework based on Design Thinking principles to operationalise the development of EERs. This framework provides heuristics for empathising 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. It delivers an easy-to-follow guideline that can be adopted and adapted in various learning contexts to create immersive learning experiences. Room2Educ8's prescribed nature makes it also approachable for commercial escape room designers who consider moving into Serious games territory. To validate the integrity and use of the proposed framework, 104 participants with no prior experience in EER design used Room2Educ8 from 2018 to 2022 to develop 26 EERs. Feedback was obtained through a combination of surveys and focus groups. The framework validation suggests that Room2Educ8 can be proposed as a valid tool for EER design. Participants found the framework very detailed, with clear and understandable steps that were easy to follow regardless of lack of prior experience in EER design. It can be used to develop a wide range of EER types covering different topics and allows designers to get a deeper understanding of the people they are designing for.

Keywords: educational escape room, design thinking, conceptual framework, game-based learning, gamification

1. Introduction

Following the shift from traditional didactic classroom models to the adoption of more learner-centred active learning approaches, escape rooms are gaining popularity as alternative learning and assessment environments designed to enhance students' learning and 21st century skills (Guckian et al, 2020). An educational escape room (EER) can be defined as an instructional method requiring learners to participate in collaborative playful activities explicitly designed for domain knowledge acquisition, skill development, or behavioural change so that they can accomplish a specific goal (e.g., escape from a physical or virtual room) by solving puzzles linked to unambiguous learning objectives in a limited amount of time (Fotaris & Mastoras, 2019). Various reviews indicate that, due to their playful nature which favours positive behaviour (Zhang et al., 2018), EERs can enhance learners' motivation, engagement, and time management, increase confidence in critical thinking and decision-making, improve knowledge acquisition and academic performance, and encourage social interaction (Veldkamp et al., 2020; Fotaris & Mastoras, 2019).

EERs frequently expose players to real-life scenarios with puzzles that fit into the story and involve interacting with many objects in realistic ways, thus bringing greater authenticity to the activity and making it more immersive (Guigon et al., 2018). Students can experience a situation in which they need to trust their own and their colleagues' competence, work together as a team, and handle both time constraints and the consequences of not working fast enough (Taraldsen et al., 2022). This approach aligns with both: a) the paradigm of narrative centred-learning environments (Rowe et al., 2011) which are defined as "a class of game-based learning environments that contextualise educational content and problem solving with interactive story scenarios"; b) the situated learning theory (Lave & Wenger, 1990), which states that situated or scenario-based learning should take place in the environment in which it would normally be applied. When used as a method of simulation-based education (SBE), escape rooms can be mapped effectively to Kolb's experiential learning cycle (Kolb, 1984), as it permits active experimentation in a safe environment, prior to undertaking concrete experiences "in the wild" (Poore et al., 2014). Debrief and reflection are essential to learning in Kolb's cycle, and the real value of the EER could be argued to be purely these elements, in common with other types of SBE (Guckian et al, 2020).

Researchers have begun to build upon the notion of teachers as designers of learning experiences for students. EERs have the potential to enable new forms of teaching, as evidenced by the rapid increase in publications related to use of escape room for educational purposes (Fotaris & Mastoras, 2019), but choices about the design of the EER room (e.g., group size, context, time, rules, etc.) can affect the learning experience (Taraldsen et al., 2022). As research in EERs is still in a preliminary phase, no unison framework about how to design them has been established yet. There is a need for frameworks, methodologies, or guidelines especially aimed at EERs that could help educators not only in creating these new learning environments (Taraldsen et al., 2022; Veldkamp et al., 2020; Guigon et al., 2018), but also in developing design dispositions that will help them adapt to the complexity of teaching in the 21st century. To address this issue, we propose Room2Educ8, a user-centred conceptual framework for EER design that can be adapted to any subject and escape room type. It is based on design thinking, a process that has been used as an instructional design method for the development of course content or teaching material, in curricular development, and as a teaching strategy to achieve subject-specific learning goals (Panke, 2019).

This article first provides an overview of the available frameworks for EER design, followed by a detailed description of Room2Educ8, so that each stage will be easy to understand and use. It then presents the method that was employed to validate the proposed framework's integrity and use. The article concludes by discussing Room2Educ8's use, study limitations, and plans for future work and evaluation.

2. Background

EscapED was the first theoretical framework to provide a methodology for creating EERs and interactive game solutions for learning and behaviour change within higher education settings (Clarke et al., 2017). It consists of six sequential steps (Participants, Objectives, Theme, Puzzles, Equipment, Evaluation), with each one of them being broken down into other areas for developers to consider. Although the escapED framework has informed the development of various EERs, either in its original form (Martina & Göksen, 2022; Löffler et al., 2021; Otemaier et al., 2020) or in a modified version (Snyder, 2018; Neumann et al., 2020), its quality and efficacy in terms of usability and usefulness has not been validated yet.

Another methodology about designing EERs is SEGAM (Guigon et al., 2018), which describes how to approach various aspects related to EERs such as constraints, pedagogy, parameterisation, tests, and background. It divides an EER into several levels, with each level representing a stage of the game and having at least one associated riddle that corresponds to one or more educational objectives (diagnostic, formative, summative or discovery of a notion).

Eukel & Morrell (2021) presented a cyclic design process to create, pilot, and evaluate EERs comprising 5 steps: Design, Pilot, Evaluate, Redesign, and Re-evaluate. While this approach offers some generic advice on EER development, it appears to be a simplified and iterative adaptation of the waterfall project management methodology. The provided information for each step lacks depth and there is no evaluation of the proposed method.

Nicholson and Cable (2021) proposed a framework that enables the setting of specific learning objectives and individual learning outcomes for students in an EER by mapping them against 7 dimensions (setting, social, story, skills, strategy, simulation, self) to build a cohesive interactive story that provides learning opportunities. Although the authors give instructions on building an EER using this framework, they do not provide information about the framework's own evaluation.

The COMET framework was developed as a step-by-step approach to designing EERs that would meet specific medical knowledge, skills, attitudes, and safety objectives while considering the unique dynamics of an interprofessional team (Dittman et al., 2022). It comprises 5 components (Context, Objectives, Materials, Execution, Team Dynamics) and was piloted in a workshop aimed at enabling small groups to collaboratively design an interprofessional escape room.

Despite their different approaches, the aforementioned frameworks share one thing in common: they rarely validate the quality and efficacy of the frameworks themselves in terms of usability and usefulness, opting instead to assess the impact on learning of a single prototype escape game that was developed using the

particular framework. Room2Educ8 addresses this issue, as it was validated by 104 participants who used it to develop 26 EERs on various subjects.

3. Room2Educ8 framework

Room2Educ8 aims to allow practitioners to develop their creative confidence, which is required for game-based learning to be fully realised, by engaging in hands-on projects that focus on building empathy, encouraging ideation, and fostering active problem-solving. Its process can be described as a cycle of (1) empathising and observing, (2) defining the problem, (3) contextualising, (4) designing, (5) briefing and (6) debriefing participants, (7) prototyping and playtesting, (8) documenting, and (9) evaluating (Fig. 1), with the designers also reflecting and devising throughout the cycle. These steps were influenced by a typical design thinking process of (1) empathising and observing, (2) defining the problem, (3) creating ideas, (4) prototyping, and (5) testing.



Figure 1: Room2Educ8 framework

3.1 Empathise

The first step of Room2Educ8 calls for EER designers to gain an understanding of both the people they are designing the EER for and the problem they are trying to solve. Techniques such as focus groups, interviews, observations, and surveys, as well as data from academic records can be utilised to collect information about learners' demographics, educational background and needs, attitude towards subject matter and playing for learning, player role (e.g., students as players / designers / observers), and skill level. The collected data can then be used to build learning personas, i.e., fictional characters who represent certain traits and qualities of the target audience for whom the learning experience is designed for (Quintana et al., 2017). These should be considered throughout the EER development as they can help designers to identify and understand the learning objectives, challenges and preferences of their learners.

3.2 Define

As is true when developing any curriculum, clear goals, learning objectives, and constraints are critical to ensuring that the content is delivered effectively (Davis et al., 2021). The second step of Room2Educ8 synthesises the findings from the "empathise" step to define constructs that should be closely considered when designing an EER such as: *problem statement; goals; learning objectives; constraints* (time, available space, scale, budget, curriculum, class-size, resources, language)*; required knowledge* (explicit, assumed, mix)*; group size; game type* (physical, digital, puzzle box, puzzle hunt, hybrid, serial game, escape room in a book/postcard/t-shirt)*; playtime length; game position within the curriculum*.

A specific problem can be defined by identifying the who's, what's, and why's that exist in the space around the issue, such as asking who is experiencing the problem, what the problem is, and why it matters. This should be

followed by setting up *SMART goals*. Answering questions like those in Table 1 should provide a sense of direction and motivation.

Table 1: Sample questions to define SMART goals

Goal type	Question
Specific	• What is the overall purpose of the EER? • What are the learning objectives this EER is going to support? • What type of EER will be developed? Is it going to be physical (permanent or pop-up), digital, hybrid, puzzle box, serial story, or escape room in a book/postcard/t-shirt? • If the EER is physical, where will it be located (e.g., classroom, lab, library, office, storage room etc.)? • What knowledge is required to succeed in the game? Is it explicit (students are given all of the relevant information needed within the game world), assumed (students are being tested or assessed on what they already know), retrievable (students use information retrieval skills to find what they need in the real world), or a mix? • How many participants will be in each group? • Where will the EER be positioned in the course curriculum (e.g., stand-alone activity, at the introduction of a course, during a course in addition to a lecture, as assessment, a serial story that will run periodically)? • Will you develop alone, or will you co-create with the target audience? • Will the story be stand-alone like a full movie or framed as an episode in a series with a continuous narrative arc)? • Will the EER be used as a formative or summative assessment tool?
Measurable	• How can you quantify or qualify that the learning objectives have been met? • How will the designer know when the game is successful?
Attainable	• Does the goal require the right amount of effort? • Is there sufficient budget to develop the EER? • Are the necessary resources available (e.g., space, props, equipment)? • Do learners have the necessary skills to play the game? • Are there any language barriers that may prevent participants from playing the game? • How many learning outcomes are sufficient without overloading participants?
Relevant	• Why is achieving this learning objective significant?
Time-focused	• What will be the duration of the game? • How much time will be available for self-reflection after the game? • How many sessions will be necessary to involve all participants? • What is the deadline or time restraint to develop the EER?

3.3 Contextualise

The third step of Room2Educ8 is to place the EER in a particular context that gives meaning to the activities the learners do, provides an authentic reason for escaping, and links the puzzles together in a cohesive storyline, so that participants can identify with the game experience and build personal motivations to complete the game (Clarke et al., 2017). Context includes *theme*, *setting*, *narrative* which contextualises knowledge and skills needed, *characters*, and *environment*.

It is critical to select the theme early in the design process, as it will dictate the rest of the decisions made about the game (e.g., setting, characters, tone of the puzzles). Themes such as mystery, sci-fi, horror, heist, historical, treasure hunt, and prison break are common within EER (Nicholson & Cable, 2020). The *time period* and *place* where the game will be set should be decided next, as this can determine what types of elements will be most appropriate to develop the puzzles from. A *story* should be created to provide a consistent, immersive narrative for the activity that will be introduced and discovered by the participants in bits and pieces. When crafting the story, EER designers should answer questions such as: Why are the players in the room? How did they get there? What do they need to do to escape or succeed? What is at stake if they do not escape? Why do they need to hurry? Why are there puzzles and clues in the room?

Another consideration is the *characters* that are part of the plot. In EERs, participants are expected to be an active part of the learning process, so they should be given the leading role (*protagonist*) in a story that they feel they are influencing, with an outcome they believe they can affect (Nicholson & Cable, 2020). Once this role has been decided, the other characters need to be fleshed out as well. Who are the *antagonists* responsible for the challenges and puzzles the participants must overcome? Is there an *ally* who can provide hints, tools, and instructions? The instructor usually acts as the ally to guide the learners towards success and ensure they have a positive learning experience. With compelling characters in place, the basic concept of the story can then be expanded into a storyline using the three-act structure (Skolnick, 2015).

Like the theme and narrative, the room's physical *environment* can affect the activities and overall learning outcomes. The game space becomes a memory palace whose contents must be deciphered as the participants try to reconstruct the plot (Jenkins, 2003). Choices about decoration, physical props, lighting, technology, and audio-visuals of game spaces have narratological consequences and must follow the room's theme to prevent cognitive dissonance (Nicholson, 2016). Providing on-theme costume accessories and inviting participants to dress up is also an opportunity to encourage immersivity (Lyman, 2021).

3.4 Design

The fourth step of Room2Educ8 involves designing the *puzzles* that participants must solve during the game experience, developing a *hint* and/or a *scoring system*, and defining *game rules*. Designers must determine which learning outcome each puzzle will support, understand what the participants know before they start the puzzle, and what they should know after completing it. Participants should solve every puzzle to complete the game and meet the learning objectives. Puzzles should be as self-guided as possible, make their goal easily understood, be clearly linked to clues, take less than 5 minutes to solve, and provide clear feedback when solutions are tested (Lyman, 2021). The first puzzle should be relatively easy to set the stage for success for participants, followed by diverse puzzles of increasing difficulty, which challenge participants in different ways as they progress in the game. This method can target a variety of learning approaches and is more likely to engage multiple team members, thus increasing the game's success rate.

When designing the *game flow* through which participants proceed during the game, a popular strategy is to follow a linear puzzle structure, i.e., present one puzzle at a time; solving it will then make the next puzzle available. Linear pathways are easier for participants to understand, the story flows better, and can be timed and paced, therefore less guidance is needed, and progression is easier to monitor (Guigon et al., 2018). Alternatively, in a non-linear game, multiple puzzles are available to participants all at once, and after all are solved, their outputs can be used to solve the final meta-puzzle. A flowchart showing how puzzles and clues are connected is an effective way to visualise puzzle structure.

EER designers should consider any physical and/or digital *assets* that will be manipulated to solve the puzzles or will be used as clues, e.g., the room itself as a space, containers, locks, envelopes, game tech, countdown timer to promote a sense of urgency, and narrative elements that embody the theme or setting. It is recommended to utilise assets that can be reused and/or are cheap to replace, as well as to produce refill packs with replacements for game elements in case they are misplaced or malfunction. The "one clue, one use" rule (i.e., each clue or prop is used only once to solve a puzzle and then is retired from the game) and the absence of red herrings can also improve the overall gaming experience (Lyman, 2021).

A *room layout* with clue placements and arrangements of the puzzles, as well as a flowchart mapping out how participants will navigate the room, can help manage and visualise the overall flow of the experience (Davis et al., 2021). Additionally, cards may be used to provide details of each individual puzzle and its location in the room, starting objects in each location, what prompts players to start each puzzle, and what clue/reward makes players go to the next puzzle. These techniques are useful for checking for consistency in the room design, sharing the design with others, and resetting the room.

To foster a positive learning experience, it is crucial to develop an incremental *hint system* that offers help to participants when they are stuck and fits the environment and narrative organically. Hints can be delivered to participants personally (e.g., via a TV screen, through the room's PA system, on written notes, via an app/website etc.) or by pre-set hints on apps/websites or on hint cards. Defining hint rules is recommended, especially for EERs with assessment goals (Veldkamp et al., 2020).

Finally, a *scoring system* can be used to tap into people's natural competitiveness and encourage them to do better. A final score can be awarded based on whether players were able to finish the game, the time it took them to do so, the number of hints or clues they used to solve the puzzles, or the number of puzzles they solved (Lyman, 2021). Designers should also consider whether there will be consequences to players for any errors they make, e.g., miscalculating a medical dose may result in a two-minute penalty (Davis et al., 2021). Scores leading to tangible rewards (e.g., sweets, stickers, marks, etc.) should be used cautiously, as there is the risk that players will focus on doing only what needs to be done instead of engaging fully with a puzzle, which can result in not achieving the learning outcome.

3.5 Brief

The fifth step of Room2Educ8 is for designers to consider how they are going to inform participants about the EER's backstory, objectives, and rules before the game begins. From a narrative perspective, this is Act 1 (exposition) of the three-act structure (Skolnick, 2015). A pre-game *briefing* can provide background information about the main characters (the "who"), the setting (the "where"), the time period (the "when"), and the inciting incident, as well as set up the dramatic question: what must the protagonists do to solve the problem they face? This prologue can be in the form of a pre-written script read by the EER facilitator or the players themselves. Alternatively, an introductory video can add significantly to the immersiveness of the experience, make players engage more naturally with the storyline, and heighten the sense of urgency for escaping from the room. A list of *rules* should also be provided, including information about the time limit for successful completion, forbidden items, hint and scoring system, handling props and furniture, what is – and what is not – part of the game, case sensitivity of text entry fields, consent forms, health and safety etc.

3.6 Debrief

The sixth step of Room2Educ8 is for designers to consider how they are going to make participants aware of the learning that occurred during gameplay. To provide clarity, resolution, and closure to the story, a *debriefing* session upon completion of the EER may begin with an *outro video* showing what happened at the very end of the story, what participants did in the game, why doing that was important, and how their actions improved the circumstances of the game's characters. Next, the facilitator should guide participants in reflecting on their performance, the game content, the puzzles, the skills needed to solve them, and their overall experience, and then use this discussion to clarify teaching points. As participants may desire feedback on observed team-based skills, open-ended questions can be used to prompt dialogue about leadership, delegation, effective communication, and task assistance (Zhang et al., 2018). The debriefing may be concluded by giving away *revision material* that summarises key learning outcomes the participants explored during the game, and by taking a *group photo* (or screenshot) of participants optimised for social media.

3.7 Prototype

The seventh step of Room2Educ8 is for designers to consider how they are going to *prototype* and *playtest* the EER. Once the design is finished, the next steps are to make a *lo-fi* testable prototype, have participants with similar skill sets to the intended learners playtest it, return to the design process to solve problems that came up during testing, and produce a refined prototype. This cycle may be repeated several times, so it is recommended to use few resources in creating the early prototypes, as they will most likely be changed after one play. Each playtest should address issues about realistic playtime, difficulty level, puzzle mechanics, relevance to learning objectives, quality of hints, and cohesive narrative. Testing individual puzzles, paper prototypes, the debriefing structure, and the full game at different stages will provide important feedback to improve the design and achieve game balance and playability (Davis et al., 2021).

3.8 Document

The eighth step of Room2Educ8 is for designers to consider how they are going to *document* the process of developing the EER. A highly descriptive *game design document* (GDD), created and edited throughout development, can act as a guiding light and help the design team to refine scope and production needs. General anatomy of a GDD includes a game overview with general information about the EER and its learning objectives, followed by sections that describe each part of the design (e.g., puzzles, narrative, assets, etc.) in progressively more detail. It is recommended to produce two additional documents: a) a *facilitator guide*, which should contain the learning objectives, briefing and debriefing instructions, game rules, room layout, a game walkthrough with clues and answers for each puzzle, rules and/or pre-set times for providing hints; b) a *set up/reset guide* with clear instructions about how to set up and reset the game for another play-through.

3.9 Evaluate

The ninth and final step of Room2Educ8 is for designers to consider how they are going to *evaluate* the EER experience and assess whether the EER met its goals and objectives, what aspects of the game contributed to or detracted from this, and how the learning experience could be improved. Instructor *observations*, review of video footage from game sessions, and learner feedback using post-activity *interviews*, *focus groups*, *surveys*, and the debriefing session are common methods to gather this information. When the EER is used as a tool to assess knowledge and/or soft skills, the achievements on the learning goals can be measured by means of a *pre-/post-/delayed post-knowledge test* (Veldkamp et al., 2020).

4. Room2Educ8 validation

Since the proposed framework is based on design thinking principles, it was embedded in a compulsory postgraduate module named "Design Thinking" for the MSc in User Experience Design course at the University of Brighton, where students had 13 weeks to collaboratively design, develop, facilitate, present, and document a one-hour EER experience using Room2Educ8 for their coursework (Fig. 2).



Figure 2: Study participants using Room2Educ8 to design an educational escape room's puzzle flow

To assess Room2Educ8's integrity and use, a mixed-methods internal validation study, which was based on Instructional Design model validation (Richey, 2005), ran for 4 academic years (2018-2022) with a different cohort of students every year. A total of 104 students (*N*=104, 48 males, 56 females) aged 21 to 32 with no prior experience with EER design worked in groups of 4 and created 26 EERs (14 digital, 8 physical, 4 hybrid). 16 EERs focused on cybersecurity awareness, 6 on Information and Communication Technologies, and 4 on information literacy. All students completed a survey of 10 statements measuring overall perceptions of Room2Educ8's clarity, usability, and usefulness (Table 2). The perception scale was a five-point Likert scale ranging from "1 – strongly disagree" to "5 – strongly agree". To support or refute the quantitative findings, qualitative data were collected through 26 focus groups (4 students per group) moderated by a lecturer and then analysed using content analysis.

Survey results in Table 2 indicate that the framework is very detailed, with clear and understandable steps (4.25) that are easy to follow regardless of lack of prior experience in EER design (3.89). It provides designers with a comprehensive view of EER design (4.41) and can be used to develop a wide range of EER types (4.02) covering a variety of topics (4.09). Using Room2Educ8 can increase confidence in EER design (4.44) and help to develop 21st century skills such as empathy (4.27) and teamwork (3.94). The focus groups also yielded similarly positive results, as is evident by the sample responses in Table 3. Although data collection was repeated 4 times in total with 4 different cohorts of students, this did not affect the study results which appeared very similar in every run.

Table 2: Survey results (N=104)

Survey statement	Mean	SD
I feel that each step in Room2Educ8 was easy to understand	4.25	0.83
I believe that all steps in Room2Educ8 are necessary	3.95	0.89
The use of Room2Educ8 helped me to get a comprehensive view of EER design	4.41	0.60
Room2Educ8 can be used to design a variety of EER types (e.g., physical, digital, hybrid)	4.02	0.74
Room2Educ8 can be used to design a variety of EER topics (e.g., medical, STEM, literature)	4.09	0.66
Room2Educ8 can be used to design EERs regardless of prior experience	3.89	0.96
The use of Room2Educ8 increased my confidence in designing EERs	4.44	0.63
I plan to reuse Room2Educ8 to design any future EER	4.04	0.99
Room2Educ8 has helped me to work effectively in groups	3.94	1.03
Room2Educ8 has helped me to get a deeper understanding of the people I am designing for	4.27	0.86

Table 3: Sample focus group responses

Topic	Response
Clarity	"At first, I was overwhelmed by the large number of Room2Educ8 steps, but the detailed instructions made them easy to follow."
Usability	"Although I had never heard of escape rooms before taking this class, Room2Educ8 made designing an EER pretty straightforward."
Usefulness	"I must admit that I was sceptical about this assignment at first, but by the end I could clearly see how Room2Educ8 can be an effective tool to learn and practise design thinking skills."
Communication	"Despite being rather shy and quiet as a person, designing an EER with Room2Educ8 increased my confidence and made it easier for me to express my ideas and communicate with my classmates."
Teamwork	"This was an excellent activity for team members to get to know each other. We gelled very well, and everybody contributed to the project."
Motivation	"That was by far the most fun I had in an assignment. I will definitely use Room2Educ8 to design my next EER, this time in VR."
Formality	"According to the framework, we had to connect every puzzle to a learning objective, and that required a lot of effort."

5. Conclusion and future work

The rationale for developing Room2Educ8 was to translate EER design into practical steps that educators and other interested parties with no prior experience with the escape room format can reasonably implement for their own teaching practice. Its prescribed nature makes it also approachable for experienced commercial escape room designers who consider moving into Serious games territory.

The framework enables the mapping of learning objectives against puzzles and narrative to build a cohesive interactive story that provides contextually immersive learning experiences. Educators and researchers can use Room2Educ8 with any core content subjects to develop EERs that reinforce or teach critical concepts using auditory, visual, and kinaesthetic modalities. Additionally, they can assess their students' soft skills by having them use Room2Educ8 to design EERs. As the framework's design thinking approach fosters many of the desirable traits identified as 21st century competencies (Voogt & Roblin, 2012), it enables its users to acquire knowledge, skills, and attributes needed for collaborative problem solving. Using Room2Educ8 may also contribute to the development of judgement, self-reflection, and practical wisdom, as it seeks to improve the learning experience in an inclusive way by incorporating the views and insights of the learners themselves. The human-centredness of such a framework can serve to nurture qualities necessary for social interaction and the cultivation of empathy.

A limitation of this study is that, although the expected target audience for Room2Educ8 is educators, it was used and validated by participants who lacked a background in Education studies. Therefore, future works will include similar trials with Education students, pre-service teachers, and professional practitioners already

working in the education sector in order to observe any similarities or differences towards already tracked reactions to the proposed framework. Another limitation is that Room2Educ8 was only validated internally, i.e., its validation focused upon the integrity of the framework and its use. To support the study findings, a follow-up external validation addressing the effects of using the framework – the developed EERs themselves, and their impact on learners – will be conducted in the future.

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Students' Learning Experience in Online Games-Based Sex Education in Thai Secondary Schools

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Abstract: In sex education, traditional teaching approaches that place the teacher in the centre of learning provide little opportunity for promoting the development of students' sexual knowledge, maturity, self-confidence, communication skills, and well-rounded personalities. In Thailand, this traditional approach has an impact on teenage students' effective learning for the Comprehensive Sex Education (CSE) curriculum through their behaviours and attitudes about sex-related topics. Moreover, CSE does not cover many approaches such as discussions and debates to promote students' analytic and critical-thinking skills related to sexual-related topics. (MSDHS, 2019 ; UNESCO, 2021 & UNICEF, 2016). This study investigates students' learning CSE through embedded digital Games-Based Learning (GBL) module that is delivered to Grade 7 (age 12-14) secondary school students in the north of Thailand. Researchers in this study developed a game that aims at encouraging and stimulating students' skills to analyse and critique their understanding of CSE. The purpose of this paper is to investigate how the levels of Bloom's Taxonomy have been manifested with students' learning using GBL. In the course of the study, 1152 students responded to answer pre and post-tests. The statistical findings show that students' scores in the post-test were significantly higher than those of the pre-test (withought GBL). This paper concludes that, GBL facilitated opportunities for students to conceptualize, apply, analyse, synthesize, evaluate and create their learning actively and skilfully. However, the statistical data highlights that the development measured after the use of CSE gamified syllabus does not occur at the same rate and that some skills developed at a higher rate than others. Importantly, the study found that GBL is not a standalone approach to teach CSE, other pedagogical approaches (e.g., enquiry-based learning) need to be embedded. These approaches can be implemented with or without technology, but they need to be planed ahead. Final study conclusion is that, efficient teaching of CSE is not down to students only, collective efforts of other stakeholders (e.g., parents, policy makers, etc), are needed.

Keywords: Gamification, Bloom, Learning, Sex Education, Technology, Teenage

1. Study Background

Thailand has the highest teenage pregnancy rate in South-East Asia. Infection rates for sexually transmitted diseases are rising while the age of first sexual intercourse has decreased (Panyayong, 2010). According to the Ministry of Social Development and Human Security (MSDHS, 2019), young people are particularly at risk of unsafe sexual behaviour, as about 39.5 out of 1,000 teenage girls between 13-19 become pregnant, a ratio that is higher than that of the global average. The main consequences of adolescent pregnancy and parenthood are economic and social in nature, as adolescent parents face increased barriers to educational achievement and social stigma in their public and private lives. Consequently, it is well-documented that sex education can have beneficial effects on teen's sexual behaviour (UNICEF, 2016; MSDHS, 2019).

According to Boonmongkon, *et al*. (2019) CSE provided in most schools in Thailand, but its implementation is incomprehensive and inconsistent across different types of schools. Pedagogy was found to be heavily lecture-based, while the class environment was not comfortable for many students. Researchers stated that strategies are needed to address implementation shortcomings to have sex education more comprehensive in Thailand. Findings from a UNICEF study (2016) indicate that many students lack the understanding and awareness about contraception as well as opportunities to develop communication and negotiation skills that they need in their sexual lives. In addition, the study reveals that there is lack of classroom engagement and interaction in the teaching methods and a need to provide children and young people with critical thinking skills to counteract their negative sexual attitudes. To this end, the MSDHS (2019), one of the main solutions that rely on education to educate teens about safe sex, initiated different projects (e.g., radio programmes and social media) to deliver sex education to young people and give them a forum to discuss sexual issues. Moreover, the Thai Ministry of Public Health and non-governmental organizations like the PATH Thailand Foundation (https://www.teenpath.net) recommend that CSE needs to be designed and delivered through activity-based

instruction methods and exchanges of opinions between students using activities that stimulate critical thinking and a dialogic.

UNICEF study (2016) recommends embedding a greater variation of learning activities into the teaching, such as discussions and debates, role-playing, drama, games and in general activities that require interactions and engage learners. According to UNESCO (2021), teachers are teaching the content which they themselves have received training in, and for which they have been provided teaching resources, such as textbooks and teaching plans. The study recommended to create online learning materials such as games to provide alternative channels for learning about sexuality and related topics, both for students and for teacher training. Last and not least merit of GBL is that it includes knowledge transfer from the virtual to a real-world environment, provides immediate feedback in response to mistakes, and offers a learning pace tailored to individuals (Prensky, 2003; Van Eck, 2016). In addition, according to Cicchino (2015) GBL intervention and cycles of gameplay are effective in promoting higher levels of critical thinking, including the development of independent beliefs, prior to engaging in collaborative discourse and providing opportunities for guided reflection. Nevertheless, as the new national education plan of Thailand, which has been implemented from 2017 to 2036, aims to equip Thai students with skills necessary for the 21st century such as critical thinking (Saengpassa 2017). Using technology in teaching and the affordance of online learning is an essential part of educational reform in Thailand will allow Thai students to become self-learners and will hopefully move Thailand in the direction of student cantered´ learning,

This research manifests students' learning in CSE in Thailand using digital gamified content. Student's experience is portrayed through the six levels of Bloom's Taxonomy models (Armstrong, 2010), which is used for classification of educational learning objectives to define and distinguish different levels of human cognition—i.e., thinking, learning, etc.

2. Literature review

2.1 Bloom's Taxonomy

In education, Bloom's Taxonomy of learning is still one of the most modern and central models of developing cognitive skills (Bloom, 1956). The Taxonomy captures the nature of thinking and builds the base for learning through its six different levels of interaction with knowledge. The pyramid-shaped classification demonstrates key skills at both lower (remembering, understanding and applying) and higher (analysing, evaluating and creating) planes of reasoning knowledge. Intrinsically hierarchical, Bloom's Taxonomy uses the levelling of thinking skills ascendingly which, arguably, attributes to the controversy from traditional educational patterns. At the bottom of Bloom's Taxonomy (see figure 1 below) lies retention which is a foundational level in understanding core knowledge that can facilitate thinking about the subject (Mhlolo, 2015). Despite its relevance to learning, the over-reliance on lower order thinking skills may feature rote learning and traditional classroom instruction in schools (Ananiadoui and Claro, 2009). Arguably, this may also hinder the learners' critical engagement and creativity in the 21st century classroom.

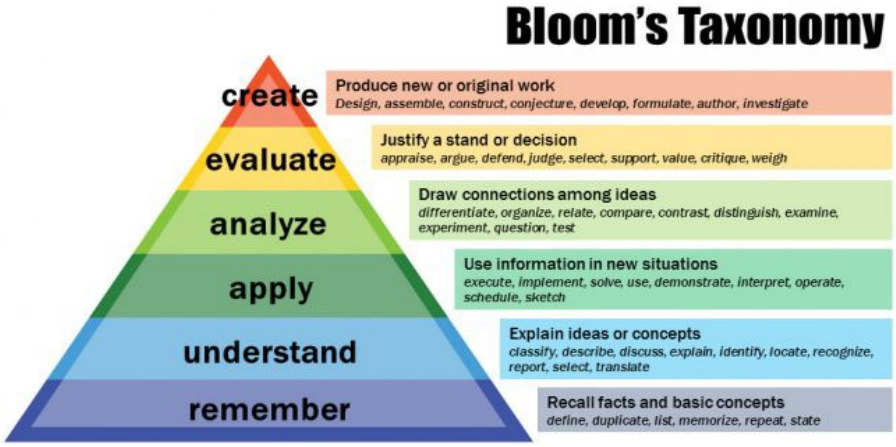


Figure 1: Bloom's Taxonomy (Armstrong, 2010)

In a cordial context, the teaching, as well as learning, developing reasoning through analytical, problem-solving, critical thinking and micro-skills such as classifying, summarising, inferring, interpreting and explaining have been recognised as key indicators of the quality of students' learning and should be integrated in the curricula to

nurture the learners' 21st Century capabilities (Conklin, 2005). Developing these skills requires a factual knowledge domain to be taught through (Ananiadou and Claro, 2009), hence the need of the integration between lower and higher order thinking skills. Equally, they need a medium in which teaching can be effective and learning meaningful. We argue that gamification (gamified content) is the best agentic environment to activate these skills. Therefore, as the purpose of this student is to manifest students' learning experience in using digital games to learn CSE module. Bloom's Taxonomy classified model including both levels of order thinking; High Order Thinking (HOT) (analyse, evaluate and create) and Low Order Thinking (LOT) (remember, understand and apply) would help this study to answer its question and differentiate different levels of students

2.2 Gamification versus Games-Based Learning (GBL)

GBL and gamification are two concepts that have been used interchangeably in literature. Therefore, in this study we differentiate between them and clarify our standing point. GBL is the use of digital games with educational objectives as tools that support learning processes in a significant way. GBL is aimed at teaching a discrete skill or specific learning outcome, rather than being a complete pedagogical system (Fernandez-Antolin *et al*., 2020). Gamification is digital game in a non-gaming context for the purpose of engaging learners, motivating activities, enhancing learning, and solving problems (Haruna *et al*., 2018) and to foster their interest in a certain area that may enhance learning (Haruna *et al*., 2018; Dominquez *et al*., 2013). Gamification increases motivation and engagement in the learning task, encourages student participation; improves learning outcomes and soft skills (Melville *et al.,* 2018; Huang *et al.,* 2020). Therefore, in the study context with gamification, learners are expected to apply their learning, solve problems and synthesize their decisions. Although gamification has shown great potential in sexual health education, little is known about its application and effectiveness when embedded in teaching methods (Haruna *et al*., 2018). In Thai CSE, the game scenarios are situationally experienced quoted from real life experience, and facilitate relating existing knowledge to newly acquired knowledge, looking for meaning and making connections between facts. Therefore, in the gamified module design for this study, we turned the entire learning process into a game. (1) narratives that amend the setting for a certain task that includes problem solving and decision making (2) design of dialogic approach between learners and avatars (3) provision of gameplay elements (achievement badges, points and progress bars) to motivate and engage learners (Hanus and Fox, 2015).

The reason that gamification is underpinning this study refers to the study research questions about student's achieved learning objectives, as according to Arnab *et al*., (2018), game design and computational process support the thinking skills based on Bloom's Taxonomy. Gamification is often associated with HOT and constructivist approaches to learning that offers a chance to focus class time on the higher forms of cognitive work (application, analysis, synthesis, and/or evaluation) (Charsky and Mims 2008 and Marinensi *et al*., 2020). Higher-order thinking is defined as the group of skills that occupy the upper end of Bloom's Taxonomy which include, from lower to higher order: knowledge, comprehension, application, analysis, synthesis and evaluation. The final three skills fall within the domain of higher order thinking skills and are particularly valuable for deep learning (Bloom, *et al*. 1956). A constructivist approach suggests that learning occurs as part of an active process of constructing ideas and relationships in the learner's mind rather than simply being exposed to information (Piaget, 1967). Learner's further their knowledge and understanding through their own observations and experiences gained through experimentation. Applying an experimental approach to learning about bacteria in the real world could carry the risk of dangerous outcomes such as contamination or infection, especially in a healthcare setting. A game, however, provides a safe 'sandbox' (Gee 2003) environment for experimenting with bacteria, as well as the ability to accelerate natural processes so that they can be more easily visualised, and experiments undertaken. Therefore, we developed the module gamified activities (achievement badges, points and progress bars) in correlation with the 6 levels of the Bloom's Taxonomy.

2.3 Game Design and instructions to play

Based on the selection of CSE tutors from the CSE syllabus, the game focuses on two agreed CSE-related topics; sexual harassment and sexual abuse. It is worth noting that the game language is the students' and teachers' native spoken Thai.



Figure 2: Game home screen

2.3.1 Part 1 – Making Robot (Topic: Sexual Harassment)
In this part, each player needs to construct a robot out of eight different parts.

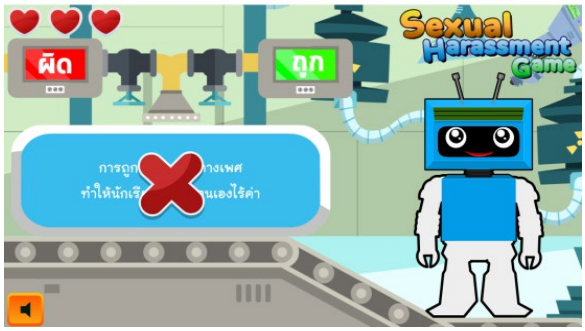


Figure 3: Part 1 – Making Robot (topic: sexual harassment)

2.4 Game Instructions
To collect the parts, a statement which may be right or wrong will be flagged and the student needs to think and decide whether this statement is 'correct' or 'wrong'. If the statement selected by the student is 'correct', it will build one part of the robot. If it is 'wrong', the student will lose one of the five red hearts above, and no parts will be added to the robot shape. The student has a maximum of five 'wrong' selections, and then the game will be over. The selected statements illustrate different real-life scenarios related to topics within the Grade 7 CSE syllabus. All statements challenge the student to think critically before making a decision. Some examples of statements are as follows:

Scenario: I am shy to report sexual harassment.

- Option 1: I will keep silent, it may not happen again.
- Option 2: Bad people get an emotional payoff from seeing others afraid and upset.

Students will complete the game if they build the whole robot without exceeding the five wrong answers.

2.4.1 Part 2 – Perfect Pair (Topic: Sexual Abuse)
In contrast to the Making Robot game, the Perfect Pair game has awards, bonuses, levels and the teacher allows it to be played in groups (as a group competition game). Each player tries to climb to the top of the building and conquer each level by answering one question. Other obstacles include bombs to penalize the players if they answer the questions wrongly. The winner is the one who reaches the top of the building first.

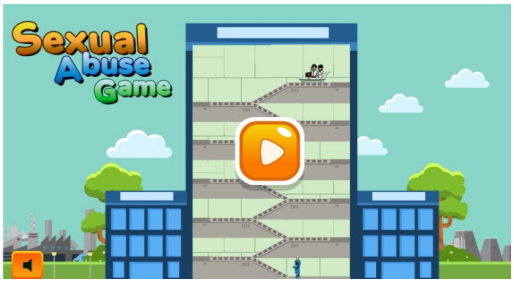


Figure 4: Part 2 – Perfect Pair (topic: sexual abuse)

2.5 Game Instructions

- In floor 1, players select one question by pressing one of the boxes:
- If the answer is right, the player goes to the second level and gets a trophy.
- If the answer is wrong, the player goes down one floor, or uses one of the awarded trophies to avoid going down.
- There is a bonus level, represented by the heart symbol where the right answer will boost a player two levels up.
- There is a bomb level – here, the wrong answer takes players two levels down.
- The winner reaches the top level first. (Ismail *et al*., 2019)

3. Methodology

This research investigates the development of critical thinking skills of secondary school (Year 7) students while studying their CSE module using gamified module that is embedded within the syllabus. The research questions guiding this study is: how the six Bloom's Taxonomy levels have been manifested in students' learning using GBL?

3.1 Participants

Addressing the research questions and context, this study used randomized controlled trials (RCT) that were collected from six secondary schools in Chiang Mai province in Northern Thailand. Initially the research invitation was addressed to 1,500 Thai students from year 7 in the 6 schools. The target sample were identified as Year 7 students who are taught the national Comprehensive Sex Education (CSE) course and receive the same content and subject timetabling (2 classes of 45 minutes each) across the two semesters and within the same academic year 2018/2019. The invited schools were sent consent forms to communicate to their teachers, students, and parents as well as an agreement to liaise the logistics of the research procedures with them. Once the consent forms were completed, a school visit was arranged to conduct the study; meet the teacher, agree on the intervention plan, and explain the procedures. The actual number of student participants was 1152 out of the 1500 invited students from 6 schools and the students were informed that the participation was optional and in no way affecting their subject grading. The study ethics were reviewed and approved by the Institutional Review Board (IRB).

3.2 Research Design

The research team developed a gamified content of the CSE test in the Thai language to compare the effect of the game on the students' results in each semester. The pre- and post-test models were used on the same set of students at different time-periods (the end of the semester 1 and semester 2). The pre-test (non-gamified) and post-test (gamified) were both undertaken under the existing traditional teaching approach (Bonate, 2000). This is to say, in the first semester, the CSE subject content was taught through face-to-face class teaching by lecturing and the use of PowerPoint slides and some contextual YouTube videos. There was no gamified content at this stage. In the second semester, the teachers continued to teach the subject - new topic- through face-to-face class teaching, together with PowerPoint slides and YouTube videos, and added the gamified content as an extra practice in class and at home to facilitate the students' independent learning via the game. The teachers' intervention was limited to monitoring the students' game access (i.e., login, selected sectional and final scores) remotely. The Figure 1 illustrates the applied steps for data collection in this study.

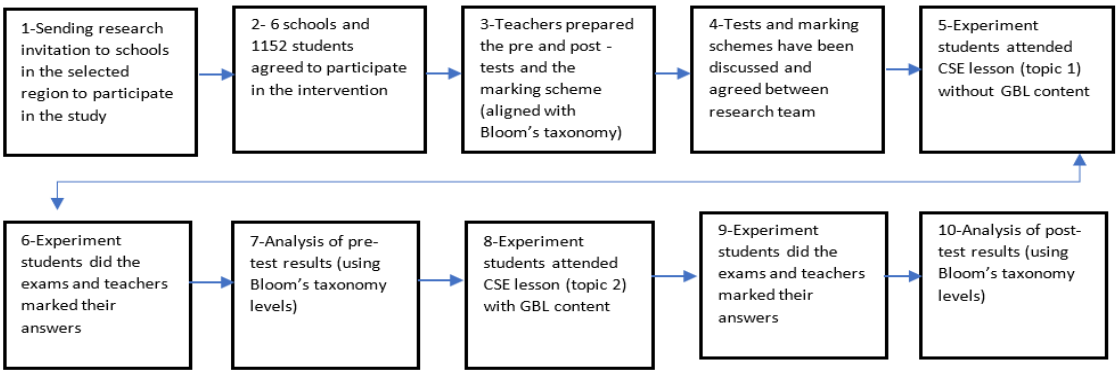


Figure 5: Research steps

The research team conducted several group meetings with the CSE teachers in each of the 6 schools to agree the intervention plan, prepare for the test questions and marking schemes that are aligned with Bloom's Taxonomy for both tests (before and after the introduction of the gamified content).

3.3 Data Analysis

The study used SPSS Version 24.0 to obtain quantitative evidence to explore the difference between pre and post-tests' results which was identified in each level of the Bloom's Taxonomy. The average mark for each question in the relevant level of Bloom's Taxonomy was calculated for the post-test and then compared to the average mark of the pre-test result of the same level of the taxonomy. This is further validated by the calculated standard deviation for each question level. Calculated standard deviation values across the different Bloom's Taxonomy levels tests the accuracy of the calculated mean and used as a representation of the level data set.

4. Findings

To answer the research question, the teachers developed six questions that were aligned with Bloom's Taxonomy to gauge the students' learning in the taught module before and after the introduction of the gamified content. The research team and the teachers worked collaboratively to pedagogically polish and finalise the questions and marking scheme and ensure that each question correlates with the six levels of thinking skills in Bloom's Taxonomy. It is worth noting that the wording of the pre- and post-test questions were slightly different to match the design of the game themes, yet they remained aligned to the six thinking levels of the taxonomy. Moreover, the Multiple-Choice Questions (MCQs) were used to offer the students alternative options to choose from, hence no open-ended questions were offered to the students. Table 1 below lists the pre and post-test questions.

Table 1: Pre- and Post-test questions aligned with Bloom's Taxonomy

Bloom's Taxonomy	Pre-test	Post-test **In Q 2,3,5;** students are given screenshots from the game in a list to select from.
Remember	Q 1- What is sexual harassment?	Q 1 - What is game 2 about?
Understand	Q 2- The correct order to report "sexual abuse" situation is……	Q 2- From the below screenshots, order the steps to report "sexual abuse" situation?
Apply	Q 3- What have you learned from the lesson that you can apply in your daily life?	Q 3- From "sexual harassment" game, select form the given screenshots a situation that you need to avoid in your daily life?
Analyse	Q 4- Reporting sexual harassment is; • Easy because • Uneasy because	Q 4- Reporting sexual harassment is; • Easy because • Uneasy because
Evaluate	Q 5- Give an example of a situation that you consider it as sexual harassment.	Q 5- In game 2, sexual harassment was found in the following situations… (select from the given screenshots)
Create	Q 6- To raise awareness about sexual abuse, I will……..?	Q 6- In game 1 about "sexual abuse", I will create ……. to raise awareness.?"

A total of 1152 pre- and post-test results were received and analysed statistically. To answer the research question, for each question aligned with a level in the Bloom's Taxonomy, we calculated the average and standard deviation of the pre and after test results. Mean was used to calculate the average score before and after using the game. Standard deviation is used in conjunction with the mean to summarise continuous data, not categorical data. In addition, the standard deviation, like the mean, is normally only appropriate when the continuous data is not significantly skewed or has outliers.

Question 1 (remember) and question 6 (create) in post-test results show an improvement in student marks with a higher average grade of 4.24 compared to 3.65 (question 1) and 2.75 compared to 3.75(question 6) for pre results. Furthermore, there is a decrease in standard deviation of student grades for post games-based learning results of 0.85 compared to 1.05 (question 1) and 1.07 compared to 1.13 (question 6) for pre results. Low standard deviation means data are clustered around the mean (central tendency). As a result, it can be said that embedding GBL for question 1 and question 6 showed a clear improvement in student results to remember and being creative compared to results without GBL.

Question 2, Question 3, Question 4 and Question 5 in post-test results show an improvement in student marks with a higher average grade of 4.08 compared to 2.79 (question 2), 4.03 compared to 3.18 (question 3), 4.21

compared to 3.32 (question 4), 3.92 compared to 3.32 (question 5) (respectively) for pre results without GBL. There is no/minor change in the calculated standard deviation of 1.09 for both pre and post games-based learning results (question 2), 1.06 for pre and 1.07 for post-test results (question 3), 1.01 for pre to 1.19 test-results (question 4) and 1.04 for pre to 1.13 post-test results (question 5). In these four questions (understand, apply, analyse, evaluate), there is an increase in the average score of post-test results and low standard deviation. However, compared to question 1 and 6 (remember and create levels in the Bloom) data is more dispersed from the symmetrical bell curve (average).

Table 2 below demonstrates the figures of average and standard deviation capturing the change, if any, in the pre- and post-test average of each question and its corresponding level of the Bloom's Taxonomy thinking skills.

Table 2: pre-and post-test results aligned with Bloom's Taxonomy

Question number	Bloom's Taxonomy Level	Average: Pre-GBL	Average: Post-GBL	Standard Deviation: Pre-GBL	Standard Deviation: GBL
Question 1	Remember	3.65	4.24	1.05	0.85
Question 2	Understand	2.79	4.08	1.09	1.09
Question 3	Apply	3.18	4.05	1.06	1.07
Question 4	Analyse	3.32	4.21	1.13	1.04
Question 5	Evaluate	3.32	3.92	1.06	1.07
Question 6	Create	2.75	3.70	1.13	1.07

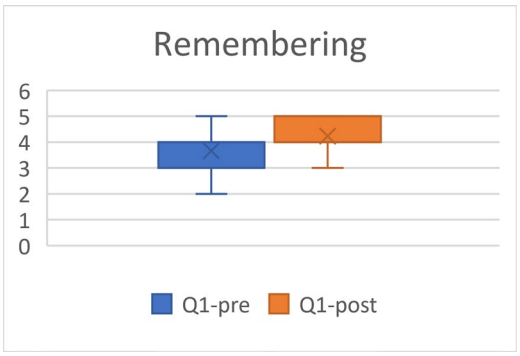
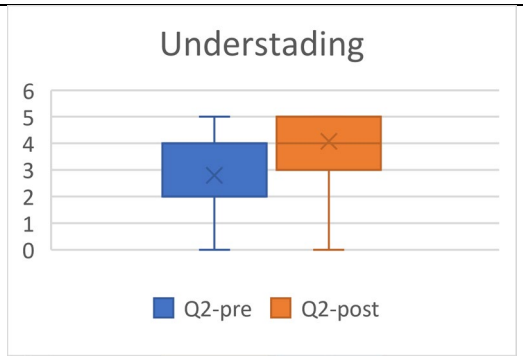
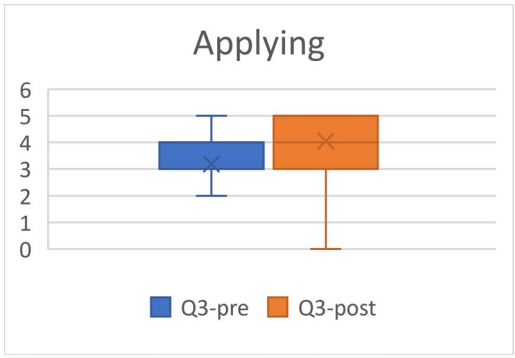
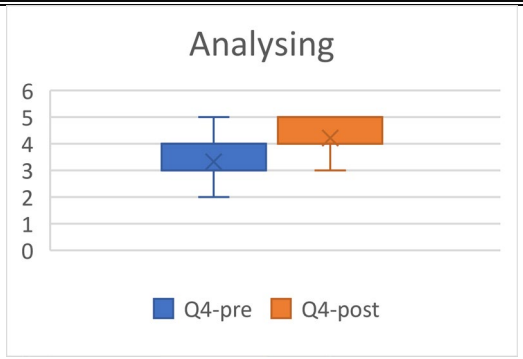
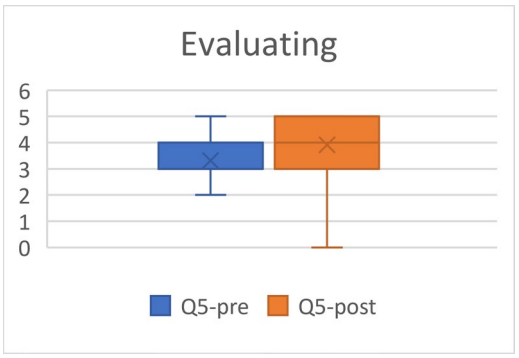
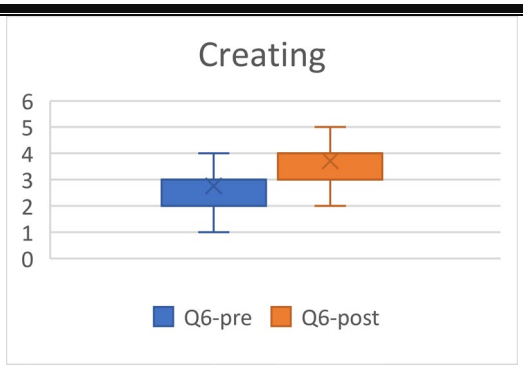
Table 2 above indicates overall statistical evidence of the development of the students' thinking skills following the use of GBL in the CSE curriculum for Year 7 students in the six participating schools. As illustrated, the development in the students' thinking skills was either significant or marginal and none of the skills remained stagnant. In other words, using the same means of comparison across all 6 levels in Bloom's Taxonomy, the average mark for each question in the relevant level of Bloom's Taxonomy was higher in the results of the post-test result compared to the pre-test results. This is further validated by the calculated standard deviation for each question level which was either similar to or lower than those calculated for the pre-test results. As seen in table 2, the calculated standard deviation values are low across the different Bloom's Taxonomy levels which indicates that the calculated mean is an accurate representation of the level data set and there is a limited variation in the question marks allocated for both the pre- and the post-test results. Aligned with the increased average of post-test scores across the 6 questions, questions 1 and 6 recorded less standard deviation than question 2, 3, 4 and 5, which indicates higher tendency of data around the average score for these two questions and that validates the accuracy of the improvement of students' results in these 2 questions after using the game.

Besides, box plots have been used to graphically show overall patterns of responses, see table 3 below.

From table 3, it is noted that, in post -test results, the minimum results are higher than post-test results in remembering, applying and creating levels. However, they are lower than the pre-test results in applying and remembering levels. However, the maximum results in post-test results are higher in all levels. Moreover, the pre-test results box is more condensed (more consistent and less variant data) compared to post-test results larger box plot.

In summary, the data provides a strong indication that the use of gamification can have a positive impact on the development of the students' critical thinking skills about CSE and that this development can show at various degrees. However, the statistical data also highlights that the development measured after the use of gamification of CSE syllabus does not occur at the same rate and that some skills developed at a higher rate than others. This is further discussed in the coming section.

Table 3: Box plots to compare pre and post-test results

Box Plots	
	
	
	

5. Discussion

The study results indicate that embedding GBL in CSE module has a significant positive impact on the 6 levels of Bloom's Taxonomy. Students' learning process begins with knowledge/memory and slowly pushes students to seek more information based upon a series of levels of questions and keywords that brings out an action on the part of the student. In this study, GBL facilitated opportunities for students to conceptualize, apply, analyse, synthesize, evaluate and create their learning actively and skilfully. However, the statistical data highlights that the development measured after the use of gamification of CSE syllabus does not occur at the same rate and that some skills developed at a higher rate than others. Figure 2 above shows that there is an evident significance in remembering, average difference in analysing and creating levels and the least difference is in understanding, applying and evaluating levels, the following section highlights the differences between these measures.

According to Sasidharan and Eng (2013); using digital gaming helps students to remember the taught content. For example, in learning a foreign language, one common problem is for students to remember and use the vocabulary they have learnt to achieve fluency. For Lantavou and Fesakis (2019), GBL helps in memorizing what students learn in English vocabulary in the classroom. However, information retention in the Thai context may not be the optimal goal in learning, as traditionally students remember the taught content based on the repetition. Many examinations in Thai mainstream education largely assess students' memorised knowledge.

Therefore, students have been encouraged to memorise the contents of books, and their critical thinking abilities to reflect on the taught information have rarely been cultivated (UNICEF (2016); Prommak, (2019)).

In sex-related topics, many students still lack a correct understanding of a range of sexuality-related issues. When asked to self-assess their knowledge, students indicated that they had a good understanding of contraception and menstruation, but only a minority gave correct answers to multiple-choice questions about menstruation or the menstrual cycle (Kunchon, 2012). Consequently, there is a need to apply the knowledge of elements of HOT skills in teaching school students in Thailand. Hence, findings in this research confirmed the affordance of GBL to increase remembering, but this increase is in conjunction with increased is aligned with increased in other learning objectives (understanding, analysing, etc) across the Bloom.

With regards to creativity, according to the study findings, it is statically significant that GBL helps students develop their creativity. This claim is confirmed by (Behnamnia *et al*., 2020) where through GBL, students will get the chance and space to define their own problems and conduct a self-assessment of their own efforts and outcomes, rather than always having work both structured, delivered and evaluated by teachers.

Figure 2 above may question why some levels (understanding, applying and evaluation) have not been increased as others (remembering, applying and creating). Hassan (2015) explains that to improve students learning when using technology, hands-on experience is recommended to improve their understanding. According to Smith *et al*, (2006), implementing technology needs to be aligned with different pedagogical approaches such as enquiry-based learning to help students understating. Therefore, GBL is not a standalone approach; it is integrated within the curriculum with another teaching approaches such as situated learning, role play.

For future development in the GBL module, deep learning that relates different knowledge across courses and link them with life skills is recommended. This is aligned with แก้วดำเกิง น (2012), suggesting life skills and the link with CSE need more portion within the content in curriculum. Also, learning activities that enhance the understanding of CSE is needed.

6. Conclusion and Recommendations

This paper concludes that digital GBL facilitated opportunities for students to remember, understand, apply, analyse, evaluate and create their learning actively and skilfully. However, the statistical data highlights that the development measured after the use of GBL in CSE syllabus does not occur at the same rate and that some skills developed at a higher rate than others. In details, remembering recorded the highest increase, followed by analysing and creating, where understanding, applying and evaluating recorded the least increased levels. The study found that integrating GBL in CSE syllabus should not be a standalone teaching approach, other pedagogical strategies (e.g., enquiry-based learning, situated learning, etc) need to be aligned with using digital gamification in learning and teaching. Moreover, to achieve higher scores in HOT levels, there is a need to embed real-life learning and hands- on applied strategies in classroom teaching.

Final recommendation is that in this study participants were secondary school students, however in sex-related topics, where sexual health is a state of physical, emotional, mental and social wellbeing in relation to sexuality, other stakeholders need to get engaged in CSE teaching and learning. These stakeholders include parents, educators, health policy makers, and religious leaders who play a key role in the adolescents' sexual cultural and social interaction to varying degrees. Therefore, planning the teaching and delivery of CSE curriculum needs to ensure the participation from all stakeholders in supporting a comprehensive sexuality education agenda that addresses the understanding and acceptance of gender and sexual diversity. Final thought for further work is that CSE teachers and their content, pedagogical and technological competence to embed GBL in CSE in their teaching practice, is an essential success factor that needs further work to complement the full picture about students' experience in learning digital gamified CSE syllabus.

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Gamification of Strategic Thinking: Using a digital Board Game on Steam

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Abstract: This is the third article in a series of articles reflecting on implementing the Commercial Off The Shelf (COTS) Board Game "Scythe" in an educational setting. It reflects on the evolution of a Game-Based Learning (GBL) approach teaching fundamental management methods and training 21st Century Skills. The first iteration of Scythe as the board game platform to train and educate students in OODA-Loop and decision support techniques was planned as a three-day on-premise workshop in February 2020. The kick-off was in November 2019 and was followed by a long self-study preparation phase. It transformed into a fully distributed learning event on short notice due to the advent of COVID-19. The second iteration, from November 2020 to March 2021, was a four-month closely supervised distributed learning experience featuring SWOT-Analysis, Kanban-Board, Scrum and other agile management methods next to the OODA-Loop. These two iterations had one thing in common. The board game Scythe was used as an analogue board game, and a Slack Workspace was used to submit pictures of the physical board game to reflect on the current situation. In the second iteration, Steam licences for the digital version of Scythe (Digital Scythe) were provided to students as a decision support tool. From November 2021 to February 2022, the third iteration implemented Digital Scythe entirely. Therefore, the final tournament and highlight of the learning experience were also fully digital, with new challenges for facilitation. This complete digitalisation also provided unique learning opportunities, particularly concerning 21st-century skills. Overall, this new seminar prototype was a huge success, and the demand for this kind of learning experience looks pretty high. It emphasises virtualisation using the popular gaming platform Steam. This article also applies a framework for distributed wargaming.

Keywords: Gamification, Scythe, Steam, Design Thinking, Distributed Wargaming, Framework

1. Introduction

This article applies a framework for distributed wargaming to the "Gamification of Strategic Thinking" seminar, benefiting from hindsight. The framework is currently under construction by the NATO System and Analysis Research Task Group 170, "Distributed Wargaming in a COVID-19 World". Educational Wargaming is a variation of Game-Based Pedagogy (GBP) from the facilitator's point of view. From the participant's point of view, it is Game-Based Learning (GBL). Katrin Becker briefly explains Games, Serious Games, Educational Games (Games for Learning or G4L), GBL, GBP, and Gamification (Becker 2021). There are takeaways from developing and facilitating wargames that apply to GBP, GBL, Serious Games and vice versa.

With the benefit of hindsight, this article reconstructs the development and facilitation of the "Gamification of Strategic Thinking" seminar applying the CASL Game Development Cycle (Figure 1) and a framework for distributed wargaming which is also applicable to other distributed GBP projects.

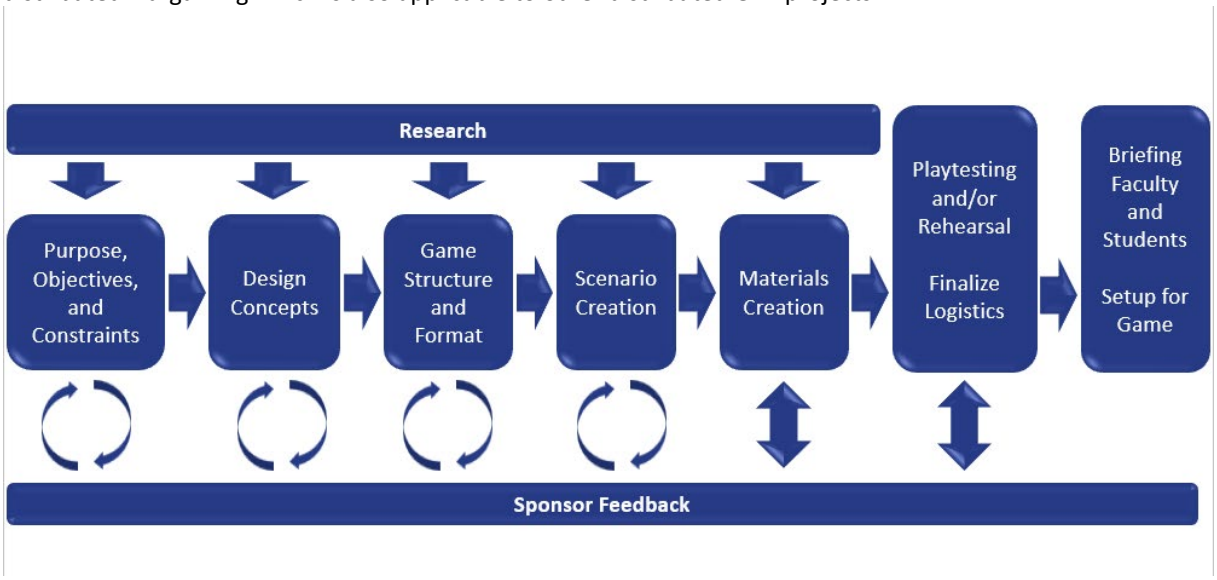


Figure 1: CASL Game Development Cycle

Figure 1 shows the Wargame development cycle of the Center for Applied Strategic Learning (CASL) (CASL 2022).

2. Why? Purpose – Educational Wargaming

After all, a wargame is a game, and game design rules apply to wargames (Schell 2020; Phillies 2014). *Design Thinking* is appropriated for game development and used to develop wargames (Wong 2020). Design Thinking can be used within the CASL Game Development Cycle. Imitation drives innovation, and game designers copy successful game mechanics from other games (Katzenbach et al. 2016, 838). This paragraph covers the first step in Herbert Simon's approach to Design Thinking (Simon 1969) *Define*. The Define step also answers the central question about the purpose of the (war)game.

2.1 Decide what issue you are trying to resolve

According to the Wargaming Handbook of the UK Ministry of Defence, wargames have two general purposes (see Figure 2) (Development, Concepts and Doctrine Centre 2017, 10).



Figure 2: Purpose of a war game

After playing the board game "Scythe", the author hypothesised that this commercially available *recreational wargame* could provide an in-depth decision-making experience. Because Scythe is a complex game, the author also hypothesised that the game should not be played single player vs single player but team vs team. Scythe would provide a set of learning opportunities centred around the 21st-century skills of communication, collaboration, creativity, and critical thinking (Battelle for Kids 2022; Fadel et al. 2015; van Rosmalen et al. 2014), focusing on strategic thinking and planning methods like SWOT-analysis (Mullerbeck 2015), the OODA-loop (Richards 2012) and Red Teaming (Howard 2021; Katz 2019; Red Teams 2018). The intended learning outcome evolved during the last three iterations of the seminar "Gamification of Strategic Thinking" (Kodalle 2021b). The facilitator introduced the Scrum framework for agile project management (Schwaber and Sutherland 2020). However, the gaming experience of Scythe is not directly applicable to real-world situations. Scythe provides a fictional model of a world in an alternated timeline. But the skills trained in the seminar and the intended learning outcome apply to real-world situations.

2.2 Agree on who the audience is

The author designed the seminar for students of the Technical University of Hamburg (TUH).

2.3 Prioritise this project in terms of urgency

Nobody prioritised this project in any way, and the author did run the seminar as a result open educational experiment.

2.4 Determine what will make this project successful

The seminar Gamification of Strategic Thinking would be successful if the intended learning outcomes were accomplished. Additionally, GBL should provide intrinsic motivation to engage the students.

2.5 Establish a glossary of terms

The relevant terms in the seminar are SWOT analysis, OODA loop, Wargaming, Red Teaming, 21st-century skills, agile project management, and Scrum. The **SWOT analysis** is a fundamental planning tool for strategic thinking, analysing strengths, weaknesses, opportunities, and threats. The **OODA Loop** applies the scientific method to the strategy-building process in four steps: observe, orient, decide, and act. **Wargaming** is a dynamic representation of conflict or competition in a synthetic environment in which people make decisions and respond to the consequences of those decisions. **Red Teaming** is testing its defensive posture against predetermined adversarial behaviour. **21st-century skills** are communication, collaboration, creativity and critical thinking. **Agile Project Management** is an incremental approach to project management, designed as a self-learning experience with feedback loops. **Scrum** is the most prominent framework for agile project management, standing on three pillars: transparency, inspection, and adaption.

3. What? A COTS Board Game for GBP

With the decision to use an already commercially available board game, we skip almost all the other steps in the CASL Game Development Cycle. There is no requirement for further research. The Faculty of Management of the TUH was the sponsor and provided funding and administrative support. There was only the question of how to implement this GBP approach.

Scythe is supposed to be one of the best strategy games ever (Zimmerman 2017). Various strategy board games offer an in-depth planning experience, like Twighlight Imperium (Military Strategy Magazine 2022). However, the playing time is often considerably longer, and Scythe provides a particular set of mnemonic hints in the design of the game components that reduce the time to learn the game's rules. For an in-depth description of Scythe within the seminar, see (Kodalle et al. 2020; Kodalle et al. 2021) and, particularly (Kodalle 2021a). Parallel to the analogue board game, Digital Scythe became available, first on Steam in the basic edition, later with additional downloadable content (DLC) and across different platforms.

4. How? A Best Practice Guide for Distributed Wargaming

This chapter applies a framework for Distributed Wargaming (DW) with the benefit of hindsight to the seminar. The best practices portion of the guide has been organised into the four domains of **Communications**, **Environment**, **Control** and **Engagement,** which encompass all aspects of the design for a DW. Many such frameworks can be created and organised in any number of ways. The SAS-170 team chose these domains as a reasonable set that would be meaningful and familiar to all wargamers. The domains are presented in no particular order, and the user does not need to begin with communications and sequentially proceed through the rest.

The first iteration of the seminar started at the beginning of the pandemic. Therefore, it was a cold start to distributed wargaming with only two weeks of preparation. The second iteration was one year later, with lots of experiences in distributed learning and collaboration by the facilitator and all participants. The third iteration introduced a new approach to facilitation, a complete transfer of all gaming activity to Steam. This was a paradigm shift in facilitation because the facilitator lost control of the technical facilitation of the game. The *White Cell* (the facilitator and his supporting staff) could not host the game on a White Cell computer, but a participant had to run the game on his/hers computer.

4.1 Communications

Communication is the essential 21st-century skill that provides the foundation for collaboration. It also enriches creativity and critical thinking. Therefore, communicating in a distributed environment is the foundation for everything else (Fadel et al. 2015).

4.1.1 Network Characterisation

The seminar was unrestricted, and the facilitator and the students used the internet. There was limited usage of the university intranet. However, the seminar leveraged several communication and collaboration applications, particularly Slack, Tello, Zoom, Steam Chat and WhatsApp. The backbone of communication was a Slack

Workspace that was supposed to be a backup channel for administration during the planned on-premise facilitation. Slack was the primary information and documentation channel for the first two iterations and Trello for the third. Comms restrictions: There are no restrictions on communication within the seminar by design. Comms channels: The seminar had different communication channels on different levels, some formal and some informal, some for synchronous (Zoom) and some for asynchronous communication (Trello, Slack, WhatsApp). The facilitator used a Zoom channel for general synchronous announcements. A Slack Workspace and Trello Boards flanked this for asynchronous communication. Of course, there was an email system. In the first iteration (out of desperation), there were many different systems and no tested structural approach. The second iteration leveraged the lessons learned from the first iteration. Trello became the visual backbone of communication, and Slack was still the primary platform for tracking the tournament at the end of the seminar. Although all teams from the THU had access to the university zoom account, and each team had their Zoom group available most of the team interaction was conducted in the specific team WhatsApp groups. Teams used various communication channels for their informal communication, including Steam chat. Network access: The collaboration networks are public but private clouds with access only to an invitation. Security breach: Due to the unclassified setting, there was no danger of a security breach. However, due to data protection regulations, participants were not required to use their real names on Trello, Slack or Steam. This caused friction and additional coordination requirement.

4.1.2 Geographic Separation

All participants were located in Germany. **Time offset:** There was no time offset; everybody was in the same time zone. **Isolated config:** The degree of isolation corollated with the relevant local restrictions implemented during the pandemic. **Clustered config:** There were no local clusters by design. Local clusters emerged due to team collaboration settings. **Co-located config:** Co-location was possible only in the third iteration and could be implemented.

4.1.3 Time Management

The first seminar understood time requirements during the first iteration through observation. Based on this observation and a good understanding of the Scrum framework, the facilitator chose to observe and teach the students daily in the second iteration. Thereby, the facilitator shifted the main effort to the four-month preparation phase. The final tournament was still a highlight and a vital aspect of explicit gamification; however, the primary training and learning took place in the preparation phase and were closely observed. The Scrum framework provides a consistent time management framework, e.g. a Scrum "Daily" is limited to 15 minutes maximum. All Scrum events are timed and follow very strict facilitation. **Active speaker:** There were no problems or specific issues with active speaker management using (only) Zoom. **Technical issues with IT platforms:** Steam is a commercial web-based gaming platform. A user buys a licence for a game and downloads the game to her private hardware. This approach was not usable for the office PCs of any attendee from the Bundeswehr. The THU bought and provided the licences for their students and, by extension, to further seminar participants. The TUH provide an entire Steam account with one licence of Scythe. The digital game "Scythe" is cross-platform available, e.g. it can be bought for Windows, Mac, iOS and Android from the game company Asmodee. However, only the licence for the Steam platform was provided. Participants needed to purchase other licences, e.g. an Apple iPad (iOS). The game is not demanding expensive cutting-edge gaming hardware. However, a multiplayer online game requires permanent and reliable connectivity. Not all participants had reliable WLAN or WIFI connectivity available. The minimum requirement per team is one performant hardware and WIFI connection.

However, the preferred option is for all team members to participate with appropriate hardware and sufficient connectivity. **Fatigue management:** The seminar was designed to minimise fatigue as much as possible by gamification. Overall, this was successful; in each iteration, teams worked overtime voluntarily and had fun doing it (Kodalle et al. 2020; Kodalle et al. 2021). **Scheduling:** In all iterations, the facilitator provided a strict schedule. In the first iteration, scheduling was based on trial and error regarding the improvised virtualisation of the seminar. In the second iteration, there was a clear understanding of the time demand, either provided by the Scrum framework or for the final tournament based on experience. However, the third iteration tried something new again by playing only Digital Scythe on Steam. Therefore, scheduling for the third iteration started with trial and error but clearly understood time demands until the final tournament.

4.1.4 Information Sharing Amongst Participants

Participants shared information based on the provided virtual environment (Zoom, Slack, Trello and WhatsApp) by their team preferences. The facilitator provided a birdview of the seminar on Trello and a Google spreadsheet.

Misc channels: Player to player: Players used most of the time WhatsApp for player-to-player communication. However, most of these communications took place in the provided WhatsApp groups. Secret communication was revealed in the AAR, including the chat protocols from WhatsApp. The facilitator did not explicitly or implicitly forbid secret communication. This secret communication was an emergent property of gameplay and immersion in the tournament.

4.2 Environment

Absent from the very first kick-off in November 2019 at the TUH, the environment was always virtual and, in most cases, the home office.

4.2.1 Game Materials and Data Management

A COTS board game provides all relevant game materials. The provided communication channels (Trello, Slack) also handled any data management issues. In the last iteration, all data management was provided by Steam. The main disadvantage was the fluidity of the state of the game. The facilitator and one additional observer had to take screenshots to document the state of the game for the AAR and evaluation. Otherwise, all information about the game is lost.

4.2.2 Visualisation

Steam provided a complete visualisation of the state of the game and gameplay for the third iteration. Trello provided a complete visualisation of the task board system for planning purposes. All moves and turns were captured and pasted in a WhatsApp channel and later pasted on a Trello board. **Context-awareness:** Scythe provides all relevant contexts. One question concerning the learning outcome was the transferability of the experience into the real world. The concept of deterrence can be felt within the game. However, is this experience transferable and applicable to geopolitical actual life events? Participants confirmed this. **Change history:** All corrections and changes are fully documented within the Slack Workspace. In Digital Scythe, no changes were possible after starting the game. The game engine took care of everything but did not provide an entire history after the game ended. **Shared viewpoint:** The viewpoint was the same for every participant during the first two iterations. Everybody could see the same pictures in the Slack Workspace. In the third iteration, all participants had the opportunity to join the game as an observer. Thereby some information was hidden from the observer, but the observer could change her point of view as preferred. **View sharing:** Any form of synchronous view sharing was conducted using Zoom. **Highlighting:** Digital Scythe did provide some nonadjustable highlighting features for visualisation purposes. **Different views:** Digital Scythe delivers a variety of different views for observers. **Collab Doc Edit:** Trello was the collaboration platform of choice and was used extensively in all three iterations. Slack was prominent in the first two iterations, and Google Docs became relevant in the last iteration. **Audio / Written:** The facilitator provided some prerecorded content for clarification, and the audiobook for the Scrum Guide 2017 were provided in the second iteration.

Backchannels: WhatsApp and Slack Workspace provided backchannels. **Plenary Discussions:** Plenary discussions were conducted with Zoom. **Breakout rooms:** Each team had a breakout room within Zoom. WhatsApp groups were also functional breakout rooms. **Text comms between participants:** Teams communicated mostly within their WhatsApp groups. **Message analysis:** The facilitator evaluated open text messages at once and secret after their revelation. The facilitator emphasised actions posted in the Slack Workspace or strategies and plans on Trello. **Game Materials & Management:** The facilitator managed all analogue game material during the first two iterations. The third iteration made this obsolete, Digital Scythe provided all game material, and Steam managed the entire game. **Accessibility:** The analogue board game was provided to the TUH. However, Digital Scythe provided much more accessibility. Configuring access to the offered Steam account was a challenge for every participant without experience using Steam. **Read-ahead package:** The facilitator provided a read-ahead package. There was a seminar resource Trello board next to the Seminar Birdview board. The read-ahead package became a living document used before, during and after the seminar. **Game control materials:** During the first two iterations, game control was firmly in the hands of the facilitator and the White Cell. The facilitator approved all changes and corrections in the state of the game. In the last iteration, the facilitator let go of all game control. Steam completely controlled the game, and the facilitator could only observe. **Player-generated data & materials:** Players could store all relevant data on dedicated Trello boards, Slack channels, or Google spreadsheets.

4.2.3 Platform Requirements

General selection principles: The facilitator chose the Slack Workspace from experience from his educational Matrix Wargame (Kodalle 2019). Trello became the central part of the seminar, particularly concerning the visualisation of agile project management. WhatsApp was the messenger everybody seemed to have on default. **Fit for purpose, reputable, adaptable:** Steam and Digital Scythe were reputable platforms and games. They were fit for purpose because the seminar was built around the game. The analogue version of Scythe allowed for adaptability, e.g. the White Cell could preselect secret missions and events. However, Digital Scythe and Steam offered no possibility to adapt these features. **Collaboration in distributed teams (clustered):** During the first two iterations, every attendee was distributed, and there was no clustering possible due to pandemic regulation. The third iteration made clustered distributed teams possible. However, the level of clustering differed from team to team. No team was entirely clustered at one location; every team always had at least one member at a different place. **Collaboration between distributed participants:** Almost all participants were distributed all the time. **Distributed vs Co-located Controllers:** All White Cell personnel were distributed during the first and third iterations. Only during the second iteration did a collocated person support the facilitator in his home office. The **Game System** was Scythe. **Tool access:** The TUH provided access to dedicated Steam accounts. WhatsApp, Slack and Trello also require individual accounts by every participant. **Productivity – ad hoc:** In the first iteration, the productivity was limited due to the pandemic and almost no experience with distributed collaboration. However, every attendee, including the facilitator, made a quantum leap in distributed collaboration. In the second iteration, the strict application of the Scrum framework increased productivity almost by default because Scrum increases productivity due to fast friction identification and mitigation. Scrum has three pillars, transparency, inspection and adaption. Everything that slows down productivity is identified daily in the Scrum Dailys and thoroughly reviewed in the Scrum Review, particularly in the Scrum Retrospective. In the Scrum Retrospective, the team reflects on the tools and their usage.

4.2.4 Classification (accrediting/security)

All information in the seminar was unclassified. The only issue that required some accrediting was the handover of Steam accounts.

4.3 Control

4.3.1 Facilitation/Adjudication

Execution control: The facilitator and the White Cell had total execution control during the first and second iterations. The facilitator moved every game component by hand, took a photo and posted it in the Slack Workspace. In the third iteration, the facilitator had no control whatsoever. One participant in one team started the game, and Steam provided the facilitation of the game. Digital Scythe is a full constructive simulation of the board game, including all the rules. Thereby it was not possible to cheat any participant. However, it was possible to make an irreversible mistake. During the first two iterations, every mistake by the facilitator was traceable and could be reversed. This was impossible in the third iteration if a team member pushed the wrong button.

Everybody was aware of this, and mistakes during data input were avoided. On the other hand, all rules were attended to by default. **State (of the game) broadcast:** During the first two iterations, the state of the game was a high-resolution static picture posted on Slack. This picture was saved and could be referred to later. In the third iteration, the state of the game was not fixed; almost a movie due to the constant streaming of the game on Steam. **Reporting (turn resolution):** The facilitator performed resolution in the first two iterations. All teams could contribute to the solution by pointing out an error that could be corrected. In the third iteration, Steam provided the turn resolution automatically. **Stage timing:** In the third iteration, each team initially played with an overall time limit. A team had one hour of total game time and was eliminated from the game if this time expired. Therefore, every team had to decide under time pressure. However, this seemed to be too difficult for the final tournament. The facilitator chose to conduct the game using another game mode with no time pressure. **Action control:** The facilitator controlled all the actions in the first two iterations. In the third iteration, he had to let go, and the participants had all control. **Discipline (around social behaviours):** All iterations relied on self-organising teams. Therefore, a high degree of discipline for all participants was required. In the end, team discipline was essential. The seminar was designed so that every participant could contribute equally to overall team performance due to the required Red Teaming. However, some participants did not contribute in the required way. The facilitator could observe this based on work results on Trello. In one case, he became aware of one team bullying a team member due to her non-contribution. **Personnel constraints:** The seminar required one facilitator, one White Cell member from the TUH for license management and organisational support and

at least one other person to help the facilitator. **Training for distributed designs:** The first iteration was a cold start with no training. Everybody did muddle through the first iteration. During the second iteration, the Scrum framework supported the learning curve. The seminar included by design all relevant aspects and increased the team performance from Scrum Sprint to Scrum Sprint to the final tournament. The third iteration provided five learning opportunities in distributed gaming on Steam before the final match. Every team was familiar with the requirements to perform at a high level during the final tournament. **Teacher (new facilitator role):** The facilitator was already qualified as a distributed teacher from the Bundeswehr. In addition, he had a specialisation in virtual teaching from Coursera. Without this experience, the first iteration would not have been possible.

4.3.2 Playtesting

Scythe was extensively playtested during development. This is one main advantage of COTS games: they are playtested thoroughly for the element of fun (Stegmaier 2015). **Distributed material generation:** The facilitator generated additional material using familiar file formats like PowerPoint and Word and distributed these materials via Slack and Trello. All participants developed material and posted it on Trello. **Load testing:** The third iteration required a lot of testing to familiarise the facilitator with the effective and efficient execution of Digital Scythe in tournament mode. **Data capture testing:** Everything was tested during the first iteration, including Trello and Slack data capturing. In the second iteration, this could be repeated with ease. However, the third iteration posed a new challenge for data capturing. This was again tested during the seminar on the fly and improved upon during the first tournament. **Platforms/IT:** Steam provides a high-fidelity platform for games in general. Asmodee provides Digital Scythe for different IT platforms: Windows, Mac, iOS and Android. Participants could access Slack, Trello, and Google Docs from Windows, Mac, iOS and Android. All applications were also available for mobile devices, providing the ability for mobile learning. **Platform functionality tests:** The facilitator tested all platforms in advance and found no issues. **Game design:** With the implementation of a fully developed and playtested game, there was no need for other game designs. **Intent specification:** See 2.1 for the purpose of the seminar. **New (wargaming) methods:** The seminar focuses on strategic thinking, plan development, execution, and friction mitigation. An additional approach was the application of agile project management (Scrum) to the learning process and framing intended learning outcomes as Sprint Goals. One unique feature of the seminar is the identical conceptual workload for each participant. In the second iteration, every participant had to play each role for a given time. Everybody had to use the same analytical skills to develop a SWOT analysis to perform as a Red Teamer. **Sponsor interaction:** The TUH acted as a sponsor, provided additional input in the kick-off, and evaluated the participants. **Funding timelines:** The seminar did not require much funding, next to the licenses for Steam accounts.

4.4 Engagement (Human Factors)

The GBL and gamification approach engaged all participants.

4.4.1 Common Elements

The main idea was to put one of the best strategy games into the learning experience's heart. **Social engagement ratio:** The gamification approach worked. The facilitator observed a high degree of engagement even after office times in the communication channels. **Response time:** The response time for asynchronous communication was overall swift. However, this depended on the team spirit. In the second iteration, response time was predicted by the Scrum framework. **Immersion:** Due to the design of the seminar, the immersion was very high. **Engagement:** Due to gamification, particularly the competition, in the end, there was a constant level of engagement because every team wanted to perform at a reasonably high level. There was also a certain degree of peer pressure within every team to keep every member on board because every member could provide the same essential contribution.

4.4.2 Fatigue

IT fatigue: The facilitator did observe Zoom fatigue. In Zoom conferences for all participants, students from the TUH usually had their videos turned off. However, videos were turned on in dedicated team meetings with the facilitator. **Processing info:** The teams from the Bundeswehr processed information faster due to a higher engagement level of each team member. The teams from the TUH processed information reasonable well on the team level. However, some dropouts did lag considerably. **Time zone differences:** There were no time zone differences.

4.5 Participant distraction

4.5.1 Location Familiarity

Due to the distribution, every participant always was in a familiar location.

4.5.2 Work/Life Interruptions

The facilitator observed work/life interruptions. Due to the high immersion and fun element, the game was played after office hours. In one rare case, a participant did not arrive for a tournament game in the final because he was a volunteer firefighter and was busy fighting a fire. **Domestic (home) interruptions:** The facilitator was unaware of domestic disruption.

4.5.3 Control Team: The White Cell

Composition & selection: The facilitator selected additional White Cell members based on their familiarity with Scythe. These were voluntary contributions. **Facilitator/Adjudicator/IT/Analyst:** The facilitator was familiar with Scythe and planned and constructed the whole seminar around this game. Additional White Cell personnel required familiarity with Scythe to contribute to AAR and strategy analysis.

4.5.4 Players

Selection: The first iteration selected students from the TUH as participants. Students from the Hamburger Fern-Hochschule were added on short notice. The second iteration added a team from the Bundeswehr Planning Office. The third iteration again added a team from the Bundeswehr Planning Office and a team from the Bundeswehr University Munich. **Comfort with tech/platforms:** There was a high degree of comfort with technology and platforms in the second and third iterations because everybody was used to the home office.

Usability (ease of use): Steam and Digital Scythe require some experience. However, this was not a problem due to the long preparation time before the tournament. **Training:** Notably, Digital Scythe provides a helpful tutorial on providing the basics of game rules and mechanics. Thereby, training for Scythe was outsourced to Steam. The seminar was, by design, a learning-by-doing experience. Thereby, all training activity was already integrated into the seminar. Mainly the second iteration depicted specific learning outcomes as training goals and framed them as Sprint Goals. **Training baseline:** The training baseline correlated with the seminar curriculum. The final tournament was the main event of the seminar and was designed to provide a stage for all teams to show off what all achieved learning outcomes.

4.5.5 Situational Awareness (SA)

The first two iterations provided situational awareness within the Slack Workspace. During the third iteration, situational awareness was provided from Steam and Digital Scythe and all non-players needed to join the game as observers. **Isolated, co-located, clustered:** The isolated distribution offered the highest SA because every participant had to use their hardware to become aware of the situation. Co-location usually results in sharing the same screen for two or more participants, which decreases SA, particularly for dedicated Red Teamer.

4.6 Participant Diversity

4.6.1 Experience With Wargaming

Participants had no prior knowledge of educational wargaming. The seminar approach was new to all of them. Some participants had limited experience in strategy games, and almost nobody did know the game Scythe.

4.6.2 Gender

There was an even distribution between the genders.

4.6.3 Age

The students were considerably younger (10 years on average) than the participants from the Bundeswehr Planning Office, all seasoned planners with a decade of planning experience. The students from the Hamburger Fern-Hochschule were also considerably older because they attended as part-time students in parallel to their regular business occupations.

4.6.4 Ethnicity

The participants from the TUH were very diverse, and almost all of them were international students from Middle East countries. However, all participants spoke German almost like native speakers. All other participants were Germans.

4.6.5 Internationalisation (Participants Able To Play From Around The Globe)

It would have been possible to play with participants from all over the world. The only restriction would be the different time zones and, thereby, the inconvenience.

5. Conclusion

After three iterations of experience observing participants playing Scythe to develop and train strategic thinking skills, the facilitator concluded that Scythe is a very engaging strategy game applicable to the intended learning outcomes. However, Digital Scythe opens new opportunities to train 21st-century skills. But there is a tradeoff. The facilitation of the game is almost entirely outsourced to the platform. Benefits are increased performance and high output (three to one). Disadvantages are reduced control and adaptability. However, these weaknesses can be mitigated, and the mitigation can be leveraged as a learning experience in collaboration in a distributed learning space. The facilitator recommends experimentation with COTS games on platforms like Steam. Any analogue board game suitable for GBL could be used in a distributed learning space with mitigations. The entire spectrum for GBP is reached if a digital version is also available.

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Modelling Core Personality Traits Behaviours in a Gamified Escape Room Environment

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Abstract: Personality Traits are one of the most important aspects of human behaviour analysis that can be widely used in a plethora of scientific fields. Nowadays, a variety of industries use self-assessment techniques to evaluate their employees or candidates to form effective teams based on the relationships between the personnel. The Big Five personality traits, also known as the OCEAN Five model, encompass an individual's behaviour on five factors: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Currently, the evaluation is based on questionnaires, which are prone to subjectivity and can be biased. In this paper, we analyse the behaviours on which each trait is based, in a series of 3D Escape Rooms with the aim of collecting metrics in a number of settings/situations to effectively assess them, with the use of gamification. Each Escape Room has unique features and simulates special occasions to monitor the player's reactions as well as gameplay style to generate specific models that calculate the level of each personality trait. The final profiling, however, is based on a combination of metrics from the different rooms since the behaviours are common and overlap with each other but can be evaluated in different situations. Results validate the mathematical models of metrics for each behaviour and crystallise the nature of the situations in which these behaviours can be modelled. Therefore, through gamification, a new generic model for categorising players, based on the Ocean five personality trait model, is generated.

Keywords: gamification, personality, behaviours, Escape Room

1. Introduction

Personality traits assessment is deemed necessary in a wide variety of areas. Personality questionnaires have been utilised as the traditional way of carrying out personality assessment. However, given the biases and drawbacks of self-reference and self-report (McDonald, 2008), a virtual environment which directly and more objectively assesses behaviour seems the ideal way to measure one's way of interacting with their surroundings.

Gamification has been proven to be a useful practice in assessing personality and soft skills in an immersive way. It is an innovative tool that promotes behavioural changes in non-game situations by utilising targeted game design principles (Robson et al., 2015) and has been applied in areas such as education, marketing, and even team building. Some of its main characteristics include leaderboards, points, and challenges (Dicheva et al., 2015). Gamification can make the entire assessment process more appealing by motivating and challenging the players while keeping records of various game aspects, different types of statistics, and how the game progresses.

One area in which these two elements can be applied is Escape Rooms (ERs) (Pan, 2017). ERs are categorised as physical and/or online, with the former being multiplayer games and the latter mostly single player. They require the player(s) to work efficiently alone or in a team, something that companies use to their advantage for evaluating and assessing their teams and employees. As previously noted, gamification requires data collection. In a physical ER, it is almost impossible to be able to systematically collect a player's or a team's statistics. Thus, the development of virtual Escape Rooms can assist in processing and analysing the entirety of the required information.

In this paper, we present a series of five unique ERs that implement a variety of puzzles, tests, and scenarios that are based on different kinds of personality traits. The goal is to generate profile models regarding the players' personality traits depending on how they interact with and solve each room.

2. Related Work

Recent research primarily focuses on ERs and their benefits in novel educational approaches (Traldsen et al., 2020), in healthcare settings (Zhang et al., 2018), and in organisational research (Cohen et al., 2020). Personality

traits have also been studied extensively primarily through the use of questionnaires for assessment (Chamorro-Premuzic et al., 2007). However, there seems to be a gap in the literature regarding personality traits and how they can be implemented in online ERs.

Regarding the former, there has been a variety of online ERs for educational purposes (Traldsen et al., 2020; Vergne et al., 2020). Most of them are quite simple, built with tools like Google Forms, alongside–Video Conference software where players must interact with each other to solve puzzles and riddles and progress to the next levels. The downsides to such ER games include a lack of statistics on how players solved the puzzles or communicated in such ER games, as well as the fact that they are usually a simulation of a game with no 3D or 2D environment to interact with. Additionally, the use of online ERs in educational contexts is primarily focused on learning process optimization. So far, little has been done to identify each student's personality traits and learning styles utilising online ERs for personalised intervention programs and new teaching techniques.

Furthermore, there has been research done about ERs and personality traits by Liapis et. al (2021). The authors presented an ER including IQ tests as riddles, alongside the typical gameplay mechanics. Moreover, Deep Reinforcement Learning agents were trained to solve the ER by finding specific buttons and solving the IQ tests. They were also emulating human behaviours through specific movement metrics. The main difference between that game and ours is that we create a series of ERs, each with its own puzzles and scenarios, presenting greater overall complexity. This allows for the examination of each trait and its behaviours more thoroughly in a customised environment.

3. Background

Personality, as a scientific term, describes a set of cognitive, emotional, motivational and behavioural characteristics one can possess. Personality traits have a long legacy as a way of conceptualising and analysing human behaviour and various theoretical contexts have been constructed to identify and organise core tendencies. There is considerable controversy about the ideal personality conceptualisation. Some of the most widespread and historically well-regarded have been Eysenck's three factor model (Eysenck, 1953) and Cattell's 16 personality factor model (Cattell, 1943). However, the one most consistently supported by empirical data is the Five-Factor Model (FFM), also known as the OCEAN Five, which stands for Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (McCrae & Costa, 1987). Existing research supports the FFM as a comprehensive and efficient tool for the description of personality traits and their relation to other phenomena (McCrae & John, 1992). Before diving into further methodological analysis, the basic structure and traits regarding each factor are presented.

Openness to Experience is characterised by intense curiosity, imagination, appreciation of art and problem solving with divergent thinking (McCrae & Greenberg, 2014). Conscientiousness encompasses matters related to order, dutifulness, and thoroughness. Conscientious people have the tenacity to complete a task despite being bored or distracted (Goldberg, 1993), while individuals low on conscientiousness can be lax, negligent or careless (Cervone & Pervin, 2013). Extraversion is characterised by sociability, assertiveness and a proclivity for positive feelings (McCrae & Costa, 1987). Generally, extraverts tend to be more energetic and person-oriented, while introverted individuals appear more reserved and timid. Agreeableness represents a tendency towards altruism, helpfulness, and compliance (Costa et al., 1991). Individuals with high agreeableness in games reveal higher levels of cooperation (Volk et al., 2011). In contrast, less agreeable individuals are more antagonistic and cynical. Neuroticism encapsulates traits such as anxiety, panic, and impulsiveness. Individuals high on neuroticism struggle to handle stress and they may get easily frustrated or irritated at others (Costa & McCrae, 1992).

Importantly, data converge to the conclusion that humans perceive virtual environments analogously to real-life environments. More specifically, they seem to retain a sense of and assumptions about personal space, invasion of which can lead to sequelae of emotional responses like distress, panic, or awkwardness. To avoid experiencing such feelings, they try to keep their distance from other avatars and avoid persistent staring, the same way they would in a real-life scenario (Wilcox et al., 2006). This very fact can point to the possibility of using virtual spaces in the study of socio-emotional responses, and in the orchestration of interventions.

4. Methodology

Our goal is to develop and configure five rooms for assessing all five personality factors – Openness, Conscientiousness, Extroversion, Agreeableness and Neuroticism – and resulting behaviours. Even though each room assesses behaviours related to each factor, some are common between traits. Thus, the player ought to play all five rooms for complete profile feedback. Preliminary designs were drawn on paper and final decisions about each room's characteristics were made. Each place has three or four rooms and is defined by its own events (different situations taking place in that scene) and puzzles to be resolved for the player to succeed.

For the implementation, we use the Unity Game Engine (Unity Technologies, 2015), a cross-platform integrated development environment, used for developing 2D/3D games. 3D implementation was chosen in order to maximise the game's realism and player immersion. Respectively, visual and audio effects are applied.

There is also a sixth place that serves as the main menu of the game and as a tutorial. The gameplay is based on a third-person character with actions like walking, running, jumping, and picking up and collecting items. These items can be helpful or misleading in solving the riddles. The player can use the drag and drop method to move some of the objects in the scene, and click on kitchen appliances, drawers and doors to open or close them. Another feature of the game is the zoom function in specific areas, as an added tool at the player's disposal to be used when needed. All these abilities and functions make it easier to observe one's interaction with the environment and obtain behavioural measurements.

On the screen, there is a user interface (UI) displayed, consisting of the inventory, a 20-minute timer, and two icons: task list and map. Additionally, messages appear during the gameplay to inform the player about their progress or even about an occurring event. Through the code scripts, we obtain the measurements by counting mouse clicks, time to solve the room, walking speed, etc. We also contemplate the strategy followed by the players to solve the puzzles, by examining specific conditions.

4.1 Escape Room Game

For each Escape Room, there is a story describing the tasks one must accomplish to win. The puzzles are related to these tasks and are designed to collect gameplay metrics for each OCEAN Five personality trait. The players have 20 minutes at their disposal to complete their to-do list and eventually "escape". In the following sections, we analyse the gameplay and the riddles of each room.

However, the ER game, including the five rooms, it is not yet available for the players' access and assessment as a demo. The puzzle ideas, and the observed behaviours, were based on how the OCEAN Five personality traits' behaviours are bibliographically analysed. The game keeps track of the players' actions and gameplay style (e.g. movements). All these observations will be summed up and the personality traits will be examined, based on the HidAC OCEAN Five behaviour simulation (Durupinar, 2011).

4.1.1 Room 1: Openness

The first ER was created to assess creativity, curiosity, and imagination; in other words, Openness. The most representative riddle developed to gauge one's creativity is the "playing the piano" task. We created this task because creativity is tightly tied with music (Webster, 2016). The story behind this riddle is the participation of the player in a piano competition. More specifically, the player wants to rehearse one more time at home before departing for the contest, but one of his music sheets is missing. The player has to find the PIN to unlock the main door and finally leave.

Specifically, the first challenge is finding the music sheet. It shows four alphanumeric characters generated randomly each time one enters the scene. Alphanumeric characters were chosen over notes so that the rationale underlying his action to pick it up (since its use is not obvious) could be examined. If he first gets to the piano and later to the music sheet, then he is able to associate that these alphanumeric characters coincide with these on piano keys. After picking the music sheet up, it is time to play the listed piano keys.



Figure 1: In-game screenshot of the music sheet placed on the piano and the room

If we examine the example displayed in Figure 1, then E6, E3, G-4, and C3 piano keys must be pressed in that exact order so as to be considered correct. Contrariwise, the player needs to play the piano again from the start. In Table 1 we can observe the most important measurements taken, as well as the outcome behaviours in this ER.

Table 1: Measuring openness trait

Riddle	Metrics	Observed behaviour
Finding the music sheet and playing the piano	We check if the player wants to play the piano without knowing the musical composition they must perform or not (Webster, 2016)	Whether or not they enjoy playing any melody on that instrument, which counts as positive/negative to their creativity and imagination
	The time it takes to rehearse the composition or by counting clicks made during their trial	Indications about the player's openness to trying new things
Find PIN code and insert it on keypad	Efficiency and time spent to spot the clues on the pots	Rates high at curiosity and exploring the environment

4.1.2 Room 2: Conscientiousness

In the Conscientiousness room, the aim is to measure the player's organisation level and whether he follows the game's flow. As highly conscientious people tend to be more disciplined and goal-oriented, they are expected to persist and work hard towards solving the puzzles in time.

With this rationale, we created a story with two riddles. The first one is a 2D jigsaw puzzle that pictures an animated character, which gives a clue that the missing ingredient is the carrots. The second is collecting ingredients according to the recipe located in a kitchen cabinet. The story of this specific ER is to manage to cook a recipe within the time boundary, because the player needs to go to an appointment. The problem is that water was spilled on the recipe and an ingredient is not clearly visible. There are two options to deal with it: guess the ingredient by collecting random food supplies and putting them in the pan, where the rest of the ingredients are put to cook, or solve a jigsaw puzzle revealing the missing ingredient.



Figure 2: In-game screenshot of the recipe that must be made, written in a notebook and the kitchen

As we can see in Figure 2, the recipe states that olive oil, pork fillet, and capsicums are needed. However, there is a hidden ingredient (carrots) in the recipe that the player needs to find and add. For the ingredients to be found, some of the kitchen's drawers and the fridge must be opened. Metrics to be calculated and observed behaviour are summarised in Table 2.

Table 2: Measuring conscientiousness trait

Riddle	Metrics	Observed behaviour
Search for ingredients reported on recipe and place them in the pan	The order in which the player picks up the ingredients and the order in which they place them in the pan (Haizel et al., 2021)	Organised and disciplined or not
2D Jigsaw puzzle	How the player places the pieces in the frame, i.e. start from the edges or randomly, as it is strategically easier	Whether the pieces/or the frame are ordered and well-organised or disordered and messy
	Time spent to associate the animated character to the carrots	Being distracted by the character or focused on the riddle's resolving

4.1.3 Room 3: Extraversion

For the Extraversion Escape Room, the aim is to gather metrics regarding the player's sociability and assertiveness. So, we implemented non-player characters (NPC) to fulfill the roles of party guests, since at this point of the story a big party to which the player has been invited is happening, as we can see in Figure 3. In this scenario, the player wishes to have another drink before leaving the party which is thought to be available at the bar. However, there is a queue in front of him. One can choose to overpass the people waiting and get to the bar without caring about appearing rude, as seen in Figure 3. The second option is to stay behind the others and patiently wait until those who precede finish. Aside from the drinks found at the bar, there is a locked drawer in the office with a bottle inside that can be accessed only by interacting with the host, who is an NPC, and asking for the key.



Figure 3: In-game screenshot of the Extraversion Room

The player is informed that the key is somewhere in the living room and he must search to find it. In order to proceed with that, the pillows on the sofa must be moved. At this point, he may throw them on the floor or simply move them around a little. His choice reflects the player's public persona.

In the scenario where the player chooses to wait at the bar rather than talking to the host, he gets informed that the drink of his preference lacks. However, he is able to fill his glass with ice so that he does not have to come back and wait again. Respectively, by proceeding with obtaining the bottle from the locked drawer, he notices, through a displayed message, that he must go to the bar either way to add some ice. In both cases, the player must wait at the bar and also talk to the host. As examined in Table 3, there are ways to estimate the level of one's extroversion.

Table 3: Measuring extraversion trait

Riddle	**Metrics**	**Observed behaviour**
Reach kitchen	Distance kept from the rest of people waiting	Patience and kindness or impatience and

Riddle	Metrics	Observed behaviour
for a drink	by measuring the waiting radius and patience which the player indicates (Liu et al., 2019)	rudeness towards others
Talk to the host and search the key to unlock the drawer	Chooses to speak to the host instead of waiting	Confidence to speak to a person the player is not so familiar with
	Makes the place untidy by throwing the pillows or keeps it clean	Whether respect to the other guests is shown, whether the person cares to keep their public Figure safe

4.1.4 Room 4: Agreeableness

Agreeableness is a personality trait associated with prosocial behaviour, like helping others and prioritising their needs. Therefore, in this ER, the player's behaviour is examined through his reactions during a friend's gathering. NPCs are introduced as our player's friends. One of them asks the player to play a specific game, but the player prefers a different one. Nonetheless, due to the way this ER is implemented, it is required to play both games suggested.

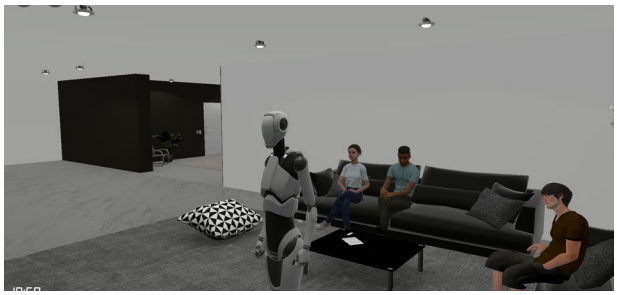


Figure 4: In-game screenshot of the Agreeableness room

Once they have both decided, they begin to play the chosen game. The games are "find the difference between two pictures" and "break the bricks". The gameplay of his friend is programmed, whilst the player's gameplay is monitored and assessed as it is reported on Table 4, where all the metrics are given. The player is able to watch his friend's progress while both playing.

Table 4: Measuring agreeableness trait

Riddle	Metrics	Observed behaviour
Making a decision about what game to play	Observing if the player retreats and plays what their friend wants or persists on playing the game of his own preference (Volk et al., 2011)	Agreeable, friendly and compromising person, otherwise unwilling and strict
		Giving priority to others' desire or his own
Playing both games	Gameplay, i.e., examining the time the player spends, clicks per second and compare it with opponent's gameplay	Being competitive by playing very aggressively - noting large percentage of clicks per second or being apathetic by letting his friend win

4.1.5 Room 5: Neuroticism

The Escape Room measuring Neuroticism is implemented in a way to elicit panic, with the scope of collecting data regarding the player's attitude in stressful situations. Neuroticism is manifested through one's emotional stability and calmness. For that reason, the story for this ER is an ongoing storm loud enough to frighten the player. A thunder strikes the oven igniting a fire, while the storm causes a power cut and turns the lights off. To simulate a storm, effects including loud rain sounds and intense light changes are utilised.



Figure 4: In-game screenshot of the Neuroticism room

For the fire event, the player has the opportunity to use the fire extinguisher hanging on the wall inside a glass box. However, he first needs to break the glass, which can only be done by using a hammer. As we aim to detect the player's patience during this weather occurrence, we intend to arouse distress by forcing him to find and unite the two pieces of the hammer, instead of it being given intact. To solve the second riddle, which is related to the electric power that went out, the player, who has been using a flashlight since the start of the level, must fix the electric fuse box to restore the power. To fix it, some cables must be connected based on their colour. Table 5 contains the metrics and the observations made.

Table 5: Measuring neuroticism trait

Riddle	Metrics	Observed behaviour
Gathering and connecting pieces of the hammer to use the fire extinguisher	Walking speed and unnecessary actions taken while collecting and connecting the pieces (Sarwar & Jaffry, 2017; Stephan et al., 2017)	Acts calmly and stabling or rushes to accomplish this task, i.e., explore the level of neuroticism
Resolving the fuse box problem by connecting same-coloured cables	Attempts to connect the cables (counting the clicks, correct - false connections, and time needed)	Checking whether he can stay collected enough to act effectively and figure out he must connect the pieces

To summarise, this ER game comprises five rooms, each designed to generate metrics for each of the OCEAN five personality traits, based on the behaviours it maps on. This can be a useful gamifilied tool and a basis for creating a new assessment way that analyses a player's behaviour and generates a profile based on it. This will ameliorate the assessment process, as it tackles limitations of self-reporting questionnaires, such as response and self-reference bias. By creating a gamified tool, there will be a more immersive and interactive way of assessing personality, as well as opportunities for analysing occurring behaviours. Promising potential in the field of assessment is offered, but further exploration in terms of reliability and validity is needed.

5. Conclusion and Future work

In this paper, we presented a series of ER games including specific types of puzzles, riddles, and events to pinpoint and assess the OCEAN five personality traits. First, we analyse the behavioural portrayal of each trait. Then, we create riddles and puzzles that generate metrics by associating each behaviour to a personality trait. Finally, we build a game in such a way that allows us to generate overall gameplay metrics for measuring each player's gaming style across a wide range of play styles. Specifically, the story behind each room and some events occurring during the game generate statistics on how a player moves and interacts with the environment. For example, during a kitchen fire-related event, such as the one developed for the neuroticism ER, individuals displaying high levels of neuroticism are more likely to struggle and get frustrated. In any case, their reactions will provide us with information regarding their emotional stability. Moreover, the employment of NPCs in other contexts is a vital technique to assess personality traits, such as extraversion and agreeableness, as they allow for the observation of social interactions.

Our first goal to explore the player's personality traits depending on how they interact with and solve each room is theoretically achieved. It must be noted that the lack of a ground truth regarding the metrics, and the behaviours to be examined in a room, is considered a limitation of our current work. However, this was our first

attempt to gain a better understanding of individuals' personality traits and how they would affect different play styles and vice versa. This study provides a foundation for future personality research.

Future expansions of our game will feature a multiplayer version, in environments with additional puzzles and numerous events that occur in different times and places. This will ensure that the metrics and the profiling will be based on real-time interaction and communication with other players. Additionally, communication templates can be created and provided to the players for a more customised game experience. Finally, the participants are encouraged to complete a reliable and valid personality questionnaire in a supervised psychological assessment context, which will serve as the basis for the game's results.

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University Students' Video Gaming: Reasons, Preferences, and Behavioural Effects

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Abstract: Research on players' reasons for video gaming, their video game preferences, and the behavioural effects of video gaming on the players tends to study those issues separately. This study attempts to explore all those issues collectively with the aim of facilitating game designers to develop appealing educational games for university students without inflicting negative behavioural impacts on the students. Relevant data from 100 undergraduates were collected from an online survey. Cluster analysis of the eight major reasons for playing video games resulted in grouping the respondents into five clusters. The cluster that rated *peer effect* as the major reason for playing is male-dominated whereas the cluster that rated *family influence* as the major reason is female-dominated. A similar analysis of the respondents' video game genre preferences reveals that the cluster favouring fighting and battle games is male-dominated, whereas the cluster favouring family entertainment games is female-dominated. Both genders enjoy playing challenging adventure-strategy games. Most respondents perceived that their cognitive functioning had improved through video gaming, but no conclusion can be drawn as to whether video gaming can improve their social and psychological functioning. Except for poor sleeping habits, most respondents had not experienced any significant negative effects from playing video games. No statistical evidence supports that playing violent video games would induce aggressive behaviours. As games that involve a high demand for players' motor skills may not be a good choice for educational games and violent games may induce poor sleep quality, it is concluded that challenging adventure games and strategy games are suitable educational game genres for undergraduate students.

Keywords: Video gaming motivation, Video gaming effects, Video game preference

1. Introduction

The number of active video gamers reached 2.81 billion globally. The number is predicted to exceed the 3-billion mark in the next two years (Clement, 2022). The increasing popularity of video games has seen young adult gamers play up to 7 to 12 hours per week (Limelight Networks Inc., 2020). Modern video games boast many game elements, including but not limited to destruction, excitement, community, challenge, strategy, completion, power, fantasy, story, design, and discovery (Quantic Foundry LLC., 2016). Some popular video game genres are casual single-player games such as *Candy Crush*, first-person shooter (FPS) games such as *Call of Duty*, battle royale (BR) games such as *Fortnite*, multiplayer online battle arena (MOBA) games such as *League of Legends*, and massively multiplayer online role-playing (MMORPG) games such as *World of Warcraft*.

Gamers play video games for various reasons, ranging from developing online relationships in the virtual world to distracting themselves from everyday hassles (Von der Heiden et al., 2019). The debate over the pros and cons of video gaming has been going on for decades. There are frequent discussions on the connection between video games and violence, particularly after one of the killers in the 1999 Columbine High School massacre was found to have a history of playing a shooting video game. While Holtz and Appel (2011), and Quwaider et al. (2019) suggested that video gaming might be related to behavioural problems in children and adolescents such as misconduct and depression, Warnick (2019) however pointed out that the research findings of neither University of Oxford nor Harvard University show any significant link between video game playing and aggressive behaviour or depression.

This research aims to study undergraduate students' motivational reasons contributing to video game playing, analyse their video game preferences, and the impacts of video gaming on them.

The research questions are as follows:

- RQ1: What are the reasons for university students playing video games?
- RQ2: What types of video games do university students prefer to play?
- RQ3: What are the impacts of video gaming on the behaviours of university students?

To answer the research questions, potential answers to the questions were obtained from the literature for the creation of a relevant online survey for undergraduate students to participate in. For RQ3, the General Affective Aggression Model (GAM) was considered for developing questions about whether playing violent video games may induce aggression (Allen and Anderson, 2017).

Knowing the answers to the above questions can help instructional designers and game designers create engaging educational games without any significant negative effects on university students.

2. Related Literature

2.1 Reasons for video gaming

Li et al. (2011) suggested that many adolescents are "avoiding real-life problems by engaging in media such as TV and video games". They further explained that the game players regard escapism as a means of managing personal mood. Kline and Arlidge (2003) reported that many gamers play online video games for social connections as they are able to meet old friends and make new friends by joining a clan in the games. Ferguson and Olson (2013) stated that young people play video games mainly because of social motives, catharsis motivations, and the search for challenges. Video games also include elements of imagination and fantasy. Molesworth (2009) found that escapism is highly linked to the desire of being in another environment in a phenomenological study. This is especially true for imaginative and fantasy game playing.

2.2 Impacts of video gaming on gamers' behaviours

2.2.1 Positive behavioural effects

Some video gaming, especially for playing FPS games, was observed to enhance cognitive functioning skills. Players were found to display faster attention allocation of higher accuracy and enhanced spatial resolution in visual processing (Bavelier et al., 2011). Such cognitive enhancements were not achievable by playing puzzle or role-playing games.

Some studies suggested that video game playing enhances problem-solving skills and working memory. In particular, complex puzzles and action sequences require memorisation and analytical skills (Prensky, 2012). Adachi and Willoughby (2013) found that adolescents who played role-playing games had their problem-solving skills improved, which were evident up to one year later. The research further suggests that more strategic video gameplay contributes to higher self-reported problem-solving skills over time which in turn helps adolescents attain better academic grades than less strategic video gameplay.

Video game playing is believed to generate positive psychological changes and provided players with positive moods. Casual puzzle video games, such as *Angry Birds* and *Bejeweled II*, were found to improve moods, promote relaxation, and ease anxiety. Players' mental stress and depression levels decreased significantly (Russoniello, O'Brien and Parks, 2009). Granic, Lobel and Engels (2014) reported that video game players often attain intense pride experienced after gaining success against great adversity.

Video games that required cooperation enhance social skills and prosocial behaviour (Gentile et al., 2009). Players often need to plan and make informed decisions on whether to trust or reject other players and learn how to lead groups effectively in virtual worlds. While many people believe that playing violent video games would make the players more hostile, Schmierbach (2010) found that when played cooperatively, violent video games in fact lower player engagement in aggressive behaviours.

2.2.2 Negative behavioural effects

Clinical distress and impairment in sleeping habits were reported to be associated with Internet gaming disorder (IGD) in (Altintas et al., 2019). Results indicated that over half the research participants reported poor sleep quality. Higuchi et al. (2005) investigated the effects of video game playing late in the night on sleeping quality for young male adults. Disturbances in sleep latency, slow-wave sleep, and rapid eye movement (REM) sleep were labelled psychological symptoms of IGD. Their results suggest that playing an exciting computer game affects sleep latency and REM sleep.

Mihara and Higuchi (2017) reported that psychological and mental distress symptoms, such as depression, anxiety, and social phobia were observed in youth who pathologically played video games. Caplan (2007)

investigated relationships between social anxiety, loneliness, and interactive online game playing. Despite feeling lonely, players preferred virtual worlds to avoid experiencing social anxiety and interpersonal problems by escaping the social world. Anderson et al. (2010) suggested that repeated exposure to violent video games leads to decreased empathy and prosocial behaviour, and significantly increases aggressive thoughts, behaviour, and hostility. Fast-paced and challenging games stimulate aggressive thoughts, and increase frustration and anger. Lo, Wang and Fang (2005) studied the effects of video games on interpersonal relationships and social anxiety levels. Their results show that interpersonal relationship quality decreased when the amount of social anxiety in heavy video game players increased. Goh et al. (2019) indicated that players had lower self-esteem and poorer psychological well-being after playing a game called *DOTA 2*. Adachi and Willoughby (2016) corroborated that competitive play increases aggressive effects in players.

To facilitate game designers to develop engaging educational games for university students without inflicting negative behavioural impacts on the students, the designers need to consider players' reasons for video gaming, the players' video game preferences, and the potential behavioural effects of video gaming on the players together. Unfortunately, past research tends to study those issues separately. This study attempts to explore all those issues collectively to identify video game genres and elements that are suitable for educational game development for undergraduates.

3. Research Design

3.1 Research methods

A quantitative approach was adopted. The target subjects were undergraduate students in Hong Kong. Other types of university students such as postgraduate and research students were excluded from this study as their demographic variables would be much more diverse when compared to the undergraduate students.

3.1.1 Data collection

An online survey with questions about the participants' demographics such as age, gender, and year of study, relevance of various reasons such as environmental and social factors that influence video game playing with answers in a Likert scale of 1 ("least likely") to 5 ("most likely"), video game preferences by genre in a Likert scale of 1 ("least favourite") to 5 ("most favourite"), and the behavioural impacts of video gaming on cognitive functioning, social functioning, psychological functioning including aggression and hostility (in yes-no format) was designed by referencing the literature (Whitbourne, Ellenberg and Akimoto, 2013; Yee 2006; Quick, Atkinson and Lin 2012). General Affective Aggression Model (GAM) was adopted to examine whether playing violent video games may induce aggression (Allen and Anderson, 2017). The survey questionnaire can be found at https://tinyurl.com/4jcxp58u. Invitations were sent to target subjects through various electronic means and 100 valid responses including 55 from male students and 45 from female students were received. The mean and standard deviation of the respondents' age distribution are 20.84 and 1.22 respectively.

3.1.2 Data analysis

While each student has his/her own video game playing reasons and game genre preferences, it is believed that students' choices tend to form clusters. For example, students who like playing shooting games are likely love playing fighting games but less interested in adventure and strategy games, and vice versa. Thus, hierarchical clustering (Everitt, 2011) was used for analysing video game playing reasons and game genre preferences. Sum of squares of Euclidean distances was used as a measure of dissimilarity in the clustering process. Based on the respondents' rating data of video game playing reasons (or preferences based on genre), the respondents were classified to different clusters hierarchically with the use of Ward's minimum variance method after z-score transformation. Then the cluster means of the concerning variables were examined for investigating the characteristics of each cluster. The behavioural impacts of video game playing on respondents were also studied for each of the revealed clusters when studying video game playing preferences. The potential gender effect within each cluster was also studied. Data analyses were done with R and SPSS.

4. Results

4.1 Video game playing reasons

Based on the respondents' rating of eight video game playing reasons including looking for a challenge, emotional satisfaction, peer pressure/effect, family influence, escapism, social connections, engaging in imaginative and fantasy play, and video game marketing, the mean score (ms) for each game play reason was

computed. The top game playing reasons are emotional satisfaction (ms = 3.54), looking for a challenge (ms = 3.45), escapism (ms = 3.41), and engaging in imaginative and fantasy play (ms = 3.37). Based on the input from individual respondents, the following cluster dendrogram is developed.

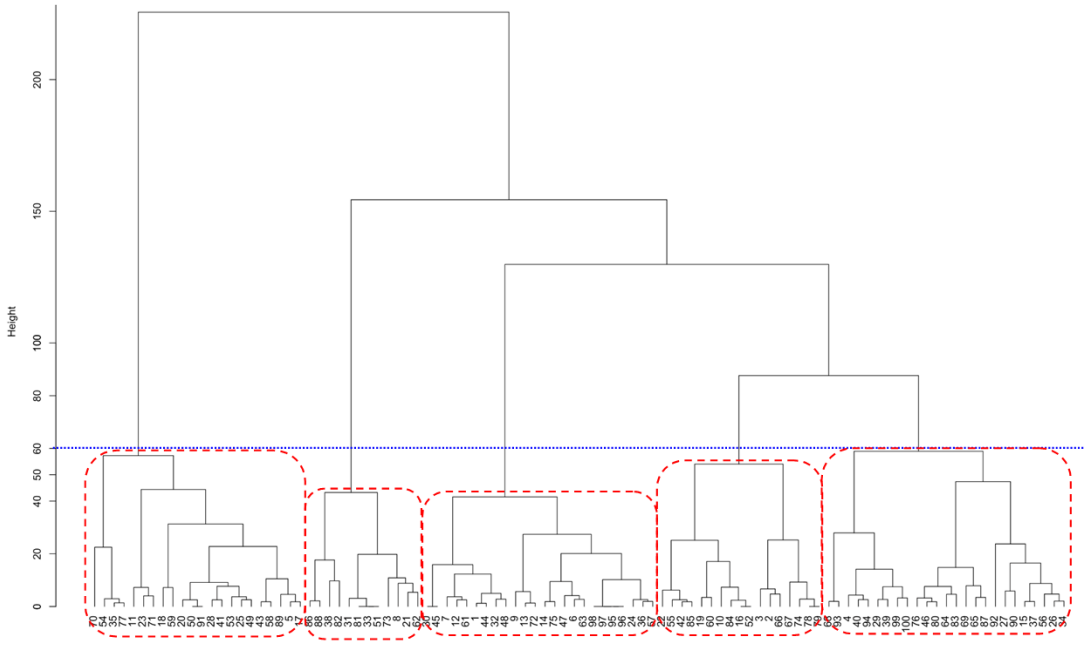


Figure 1: Cluster dendrogram for video game player reasons

The labels at the bottom of Figure 1 are the respondent number whereas the height at which two respondents (or clusters of respondents) are joined together reflects their degree of similarity (or the distance between the joined clusters). A smaller height implies a higher degree of similarity of the joined respondents in the concerned cluster. When the threshold of the height is set to 60, five clusters are formed. Further grouping of the clusters will result in a relatively large increase in the height. The means of the video game playing reasons of each of the five clusters are summarised in Table 1.

Table 1: Group means of the video game playing reasons of each cluster

cluster	Challenge	Emotion	PPressure	Family	Escapism	Socialise	Engagement	Marketing
1	0.168	0.81	-0.62	-0.18	0.5637	-0.34	0.665	-0.36
2	0.051	0.33	0.63	-0.42	-0.3649	-0.26	-0.966	0.20
3	0.625	-0.23	0.46	-0.37	0.0081	0.71	0.562	0.69
4	-0.792	-0.98	-0.64	-0.25	-0.6496	-0.64	-0.634	-0.85
5	-0.260	0.18	0.56	2.18	0.5637	0.75	0.029	0.55

Table 2: Gender distribution of respondents in clusters of video game playing reasons

cluster	Female	Male
1	0.54166667	0.45833333
2	0.47058824	0.52941176
3	0.28000000	0.72000000
4	0.27272727	0.72727273
5	0.91666667	0.08333333

The top two reasons for video game playing of respondents in cluster 1 are Emotion and Engagement. These individuals craved *emotional satisfaction* (0.81), followed by a desire to *engage in imaginative and fantasy play* (0.665). Those in cluster 2 played video games mainly because of *peer pressure/effect* (0.63) and craved *emotional satisfaction* (0.33). Respondents in cluster 3 considered *online social connections* (0.71) and were swayed by *video game marketing* (0.69). No clear reasons can be identified to account for why respondents in cluster 4 played video games. Those in cluster 5 rated *family influence* (2.18) and *social connections* (0.75) as their most preferred reasons for playing. For ease of reference, clusters 1, 2, 3, 4, and 5 are labelled by "emotion-

oriented", "peer-oriented", "socially oriented", "inexplicable" and "family-oriented" and associated with 24%, 17%, 25%, 22% and 12% of the respondents respectively. When examining the gender distribution of respondents in the clusters (see Table 2), the "socially oriented" and "inexplicable" are found to be male-dominated whereas the "family-oriented" cluster is female-dominated.

4.2 Video game genre preferences

The mean score (ms) for each video game genre preference was computed. The most favourite genres are "Adventure" (ms = 4.04), "Strategy" (ms = 3.61), "Racing" (ms = 3.47), and "Fighting" (ms = 3.41) games. However, female respondents are slightly less enthusiastic in "Racing" games when compared to the male respondents in one-tailed Mann-Whitney U Test (n = 100, p = 0.05, r = 0.13). Hierarchical clustering was again used to study the respondents' preferences for 10 video game genres including *MMORPG*, *MOBA*, *FPS*, *BR*, *fighting*, *family entertainment*, *strategy*, *sports*, *adventure*, and *racing*. By applying the elbow method, it was decided to classify the respondents to four clusters. Cluster 1 has the highest number of respondents at 44, followed by cluster 2 at 28. Cluster 3 has the lowest out of the clusters at 11, while cluster 4 has 17 respondents.

Table 3: Group means of the video game genre preferences of each cluster

cluster	MMORPG	MOBA	FPS	BR	Fighting	FE	Strategy	Sports	Adventure	Racing
1	0.23	0.037	-0.043	-0.182	-0.036	-0.025	0.259	0.014	0.39	-0.273
2	0.45	0.657	0.841	1.010	0.786	-0.071	0.059	0.753	-0.12	0.679
3	-0.67	-0.422	0.011	0.015	-0.527	-0.733	-1.553	-1.053	-1.57	-0.777
4	-0.92	-0.906	-1.282	-1.202	-0.861	0.655	0.236	-0.595	0.21	0.091

Table 4: Gender distribution of respondents in clusters of video game genre preferences

cluster	Female	Male
1	0.5227273	0.4772727
2	0.2142857	0.7857143
3	0.4545455	0.5454545
4	0.6470588	0.3529412

As shown in Table 3, respondents in cluster 1 prefer playing "Adventure" (0.39), "Strategy" (0.259) and "MMORPG" (0.23) games, and are less interested in battling ("BR"), fighting and racing games. The cluster shares a similar proportion of female (52.3%) and male (47.7%) students (see Table 4). Cluster 2 is mainly composed of male respondents (~79%). Respondents in the cluster 2 rated "BR", "FPS", and "Fighting" genres with high values at 1.01, 0.841 and 0.786 respectively. They were interested in "MOBA" (0.657), "Sports" (0.753) and "Racing" (0.679) but not keen on "FE" (-0.071), "Strategy" (0.0529) and "Adventure" (-0.12) games. These suggest that the respondents in cluster 2 may favour action games. Cluster 3, which has a similar number of male and female students in it, does not seem to associate with any video game genre preference clearly. The respondents in the cluster gave low positive ratings to "FPS" (0.011) and "BR" (0.015) and negative ratings to all remaining genres, indicating that they do not have a clear game genre preference when compared to respondents of other clusters. Respondents in cluster 4 ranked "FE" (0.655), "Strategy" (0.236), and "Adventure" (0.21) genres the highest and rated "FPS" and "BR" genres with rather low values. While the respondents in both clusters 1 and 4 are not keen on battling, fighting and racing games, a key difference between the clusters is that family entertainment ("FE") is not a favourite game genre in cluster 1 but a preferred genre in cluster 4. Both clusters 1 and 4 are gender-neutral statistically even though cluster 4 has more female respondents in it (64.7%).

4.3 Perceived behavioural impacts

With the use of a list of yes-no questions (0: No; 1: Yes) in the online survey, the perceived behavioural effects to video games players were collected. Those effects are related to the cognitive, social, and psychological functioning of the players. Statistical analysis of the effects on video games players in each of the aforesaid four video game genre preferences clusters was conducted.

4.3.1 Cognitive functioning

The respondents opined that their cognitive functioning in seven aspects (see the underlined entries in Figure 2) had been improved through video gaming. The results of a more refined analysis of whether significant improvements are found in each of the seven aspects in each cluster are shown in Figure 2.

Enhanced Concentration

cluster	0	1
1	0.06818182	0.93181818
2	0.03571429	0.96428571
3	0.18181818	0.81818182
4	0.11764706	0.88235294

Enhanced Hand-eye Coordination

cluster	0	1
1	0.06818182	0.93181818
2	0.00000000	1.00000000
3	0.00000000	1.00000000
4	0.17647059	0.82352941

Enhanced Working Memory

cluster	0	1
1	0.1590909	0.8409091
2	0.2142857	0.7857143
3	0.2727273	0.7272727
4	0.2352941	0.7647059

Enhanced Spatial Navigation

cluster	0	1
1	0.1590909	0.8409091
2	0.2500000	0.7500000
3	0.2727273	0.7272727
4	0.1176471	0.8823529

Increased Processing Speed (Reaction Time)

cluster	0	1
1	0.02272727	0.97727273
2	0.03571429	0.96428571
3	0.09090909	0.90909091
4	0.17647059	0.82352941

Improved Problem-Solving

cluster	0	1
1	0.1136364	0.8863636
2	0.1785714	0.8214286
3	0.3636364	0.6363636
4	0.2352941	0.7647059

Higher Levels of Logical Thinking

cluster	0	1
1	0.2272727	0.7727273
2	0.2500000	0.7500000
3	0.4545455	0.5454545
4	0.1764706	0.8235294

Figure 2: Proportion of respondents experienced improvement in various types of cognitive functioning (0: No; 1: Yes) in video game genre preferences clusters

The results of Chi-square test for goodness of fit show that out of the 28 cases (which correspond to the seven aspects of cognitive functioning in each of the four clusters), significant differences were found in 24 cases. The four exceptions which are highlighted in Figure 2 may be related to the small size of cluster 3 (n = 11). Similar analysis results based on the entire sample (n = 100) show that improvements are found in all the seven aspects of cognitive functioning.

4.3.2 Social and psychological functioning

Once again, Chi-square test for goodness of fit was applied to study whether any improvement in seven types of social and psychological functioning was observed by the respondents in each of the clusters created according to respondents' preferred video game genres. Significant results are highlighted in Figure 3. Out of the 28 cases, significant improvements were found in 11 cases. Those improvements are mainly related to improved strategic planning, improved team collaboration, and relief of stress. When the analysis is done on the entire sample, statically significant results are found in improved strategic planning, improved team collaboration, relief of stress, and relief of anxiety.

Enhanced Emotional Awareness

cluster	0	1
1	0.4318182	0.5681818
2	0.5714286	0.4285714
3	0.8181818	0.1818182
4	0.4117647	0.5882353

Improved Relationships

cluster	0	1
1	0.5681818	0.4318182
2	0.5714286	0.4285714
3	0.6363636	0.3636364
4	0.4117647	0.5882353

Improved Strategic Planning

cluster	0	1
1	0.09090909	0.90909091
2	0.10714286	0.89285714
3	0.27272727	0.72727273
4	0.05882353	0.94117647

Improved Social Skills

cluster	0	1
1	0.4318182	0.5681818
2	0.4285714	0.5714286
3	0.6363636	0.3636364
4	0.4117647	0.5882353

Improved Team Collaboration

cluster	0	1
1	0.13636364	0.86363636
2	0.03571429	0.96428571
3	0.27272727	0.72727273
4	0.17647059	0.82352941

Ease Stress

cluster	0	1
1	0.09090909	0.90909091
2	0.21428571	0.78571429
3	0.18181818	0.81818182
4	0.47058824	0.52941176

Ease Anxiety

cluster	0	1
1	0.1590909	0.8409091
2	0.3214286	0.6785714
3	0.3636364	0.6363636
4	0.5294118	0.4705882

Figure 3: Proportion of respondents experienced improvement in various types of social and psychological functioning (0: No; 1: Yes) in video game genre preferences clusters

4.3.3 Negative impacts

The survey includes questions about whether the respondents have been negatively impacted after playing video games. Such impacts include low self-esteem, poor sleeping habits, gaming addiction/disorders, relationship problems, social disconnection, lack of motivation, and poor academic performance. Collected data were analysed by Chi-square test. The results show that the respondents do not see video game playing entail negative effects in general. The only exception is that a significant proportion of respondents in clusters 1 and 2 suffered from poor sleeping habits as highlighted in Figure 4.

Low Self-esteem

cluster	0	1
1	0.90909091	0.09090909
2	0.92857143	0.07142857
3	0.63636364	0.36363636
4	0.64705882	0.35294118

Poor Sleeping Habits

cluster	0	1
1	0.2954545	0.7045455
2	0.2500000	0.7500000
3	0.4545455	0.5454545
4	0.5294118	0.4705882

Gaming Addiction/Disorders

cluster	0	1
1	0.6363636	0.3636364
2	0.6428571	0.3571429
3	0.7272727	0.2727273
4	0.8235294	0.1764706

Relationship Issues

cluster	0	1
1	0.86363636	0.13636364
2	0.89285714	0.10714286
3	0.81818182	0.18181818
4	0.94117647	0.05882353

Social Disconnection/Withdrawal

cluster	0	1
1	0.6590909	0.3409091
2	0.6785714	0.3214286
3	0.8181818	0.1818182
4	0.8823529	0.1176471

Lack of Interest/Motivation

cluster	0	1
1	0.4318182	0.5681818
2	0.6785714	0.3214286
3	0.6363636	0.3636364
4	0.8235294	0.1764706

Poor Academic Performance

cluster	0	1
1	0.77272727	0.22727273
2	0.82142857	0.17857143
3	0.72727273	0.27272727
4	0.94117647	0.05882353

Figure 4: Proportion of respondents experienced negative impacts in various types of cognitive, social, and psychological functioning (0: No; 1: Yes) in video game genre preferences clusters

Regarding aggression and hostility, there is no statistically proven evidence that the respondents experienced aggression and hostility after video game playing for individual clusters (see Figure 5), or for the entire sample.

Violent Thoughts

cluster	0	1
1	0.7727273	0.2272727
2	0.8214286	0.1785714
3	0.6363636	0.3636364
4	0.7647059	0.2352941

Irritability/Restlessness

cluster	0	1
1	0.5909091	0.4090909
2	0.4642857	0.5357143
3	0.7272727	0.2727273
4	0.5294118	0.4705882

Elevated Blood Pressure

cluster	0	1
1	0.7727273	0.2272727
2	0.4285714	0.5714286
3	0.7272727	0.2727273
4	0.5294118	0.4705882

Confrontational Behaviour

cluster	0	1
1	0.7500000	0.2500000
2	0.6071429	0.3928571
3	0.6363636	0.3636364
4	0.8823529	0.1176471

Excessively Competitive Thoughts

cluster	0	1
1	0.5000000	0.5000000
2	0.5714286	0.4285714
3	0.3636364	0.6363636
4	0.5294118	0.4705882

Verbal Hostility

cluster	0	1
1	0.6136364	0.3863636
2	0.3928571	0.6071429
3	0.6363636	0.3636364
4	0.7058824	0.2941176

Destruction of Property

cluster	0	1
1	0.95454545	0.04545455
2	0.78571429	0.21428571
3	0.81818182	0.18181818
4	1.00000000	0.00000000

Figure 5: Proportion of respondents experienced aggression and hostility (0: No; 1: Yes) in video game genre preferences clusters

5. Discussions

5.1 Game playing reason clusters and associated game genres

Among the five clusters of respondents identified by applying hierarchical clustering on reasons of playing video games, about half of the respondents are grouped into the "socially oriented" and "emotion-oriented" clusters. The following discussions will focus on the two clusters only, ignoring the "inexplicable" cluster and the remaining two relatively small clusters.

5.1.1 "Social oriented" cluster

The "socially oriented" cluster is male-dominated. It has 18 male and 7 female respondents. This does not mean that the male respondents gave a significantly larger weight to social connection than the female respondents. An analysis with the use of the Mann-Whitney U test shows no gender difference in the drive for making social connections in game playing for the entire sample. Anyhow, online collaboration and community challenges are possible means to facilitate social connection. The second important video game playing reason of the cluster is whether the potential players would play a video game due to its marketing efforts. Once again, no gender difference can be found for the game playing reason. In the context of educational settings, on top of rewarding students with game points in game playing, teachers may consider rewarding students by converting game points to bonus scores for assessment tasks to promote a video game to the students. Verbal praises and encouragement from teachers will also be helpful. Looking for challenges is the third important motivator associated with the cluster. The male respondents gave the motivator a larger weight than the female respondents (n = 100; p = 0.02; r = 0.23) but the difference is rather small. Relevant game elements are leader board and game levels.

In brief, educational video games for students belonging to the "socially oriented" cluster should aim to facilitate social connection, offer adequate challenges, and provide extrinsic motivators to engage their players. Since the group is male-dominated and the male respondents tend to favour adventure, strategy, first-person shooting, and racing games in descending order of preference, the aforesaid game genres appear to be reasonable choices for students classified into the cluster. However, games that involve a high demand for players' motor skills may not be a good choice for educational games as the game scores may not be able to adequately reflect a player's achievement of the learning goals (Yip and Kwan, 2006). Thus, adventure games and strategy games seem to be suitable educational game genres for students in the cluster in general.

5.1.2 "Emotion-oriented" cluster

The gender distribution of respondents in the "emotion-oriented" cluster is quite even, with the number of female students in the cluster slightly more than that of male students. In fact, the male and female respondents rated achieving emotional satisfaction as the second important and the most important reason for playing video games respectively in the entire sample. For students classified in this cluster, fostering their emotional satisfaction must be a key game feature. As engaging students in fantasy/imaginative play is the second most important game playing reason of the cluster, an attractive game context for embedding the learning elements is important. The findings reported in (Lopez-Fernandez, et al., 2019) purport that females play video games for personal preoccupation which corresponds to satisfying emotional needs and engaging in fantasy/imaginative play in the current study. However, the results of applying the Mann-Whitney U test to the data of the current study revealed no significant differences between the male and female respondents in either the needs for emotional satisfaction or the desire in engaging in fantasy/imaginative play. Note that the target subjects of the research conducted by Lopez-Fernandez, et al. were confined to female gamers.

5.2 Behavioural effects

Most respondents experienced positive effects in the seven cognitive functioning behaviours. These aligned with studies that suggested adventure games improved visual monitoring and accuracy. These occur when players scan environments for resources that help them progress through games (Zelinski and Reyes, 2009). MMORPGs enhance player response speeds and working memory when managing collected items or magic spells and memorizing enemy weaknesses.

As to social and psychological functioning, statistically proven improvements were found in the areas of strategic planning, team collaboration, relief of stress, and relief of anxiety when considering the entire sample. Past studies give similar results. *WoW*, an adventure-strategy MMORPG, allows players to experience emotions and practice team coordination skills, including social communication, group cooperation, and strategic planning pre-battle (Chang and Lin, 2014). Our results are also in line with Martončik and Lokša (2016), where *WoW* players used MMORPGs to reduce stress and experienced less social anxiety online than in real life.

Poor sleeping habits are the only negative impact of video game playing revealed by the current study. This finding concurs with Rusia and Gravoso's (2009) findings that playing MMORPGs had negative impacts on players' sleeping quality. According to Table 3, respondents from clusters 1 and 2 like playing MMORPG games. Respondents from cluster 2 particularly like playing violent games such as battling, fighting, and shooting games. Respondents in clusters 1 and 2 tend to have poor sleeping habits (see the highlighted part in Figure 5). The phenomenon can be accounted for by past research. Achab et al. (2011) reported high MMORPG addiction rates that linked to sleep deprivation with adult gamers who were mainly young adult university graduates whereas Ivarsson et al. (2013) found boys aged 13-16 years who played violent video games no more than an hour daily had lower sleep quality when compared to those who played non-violent video games.

No significant link between experienced aggression and hostility, and video game playing is found in the current study. This is consistent with the findings reported in (Warnick 2019).

6. Conclusion

The reasons for video game playing and the video game preferences of undergraduate students in Hong Kong were investigated. The positive and negative impacts of video game playing on the subjects were studied too. The findings suggest that adventure and strategy games in an imaginative and fantasy context are preferred elements of educational video games for undergraduates in general. While challenges are an important reason for video game playing, the instructional designers and game designers need to ensure that those challenges can be coped with by average students as looking for emotional satisfaction in game playing is another important

reason for video game playing. Enabling learners to establish social connections with others in the game environment would be an added benefit.

The study has several limitations. First, the small sample size may hamper the validity of some of the analyses due to type II error. Second, some of the analyses based on the results displayed in Tables 2 and 4 may be biased toward males slightly as the sample has slightly more male than female respondents. Third, while some general recommendations on characteristics of educational video games for undergraduates can be made, it is worth noting that the game characteristics that learners classified into different clusters based on game-playing reasons look for are very different. Developing multiple educational video games for the same purposes to facilitate the learning of individual users may sound luxurious. However, for massive open online courses that involve potentially thousands and even tens of thousands of learners over time, developing "personalised" educational games for individual learners is still worth considering. The challenge is how to map a learner to the best-fit cluster effectively. Machine learning techniques for recommendation systems such as collaborative filtering can be a potential solution to the problem.

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The Contribution of Game-based learning: Children with Autism Spectrum Disorder and Dyscalculia

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Abstract: This paper explores the potential of games to mathematics learning and promotion of global psychomotricity, relational/social skills in children with Autism Spectrum Disorder (ASD) and/or Dyscalculia students of Basic Education in Portugal. Inspired by Space Adventure: Defend the Planet! (SADP), an educational research-based game to children's primary mathematics' learning [PTDC/COM-CSS/32022/2017], a game-based intervention was created to psychomotricity sessions at school facilities. The study was conducted by the researcher, Superior Technician of SEN and Rehabilitation. A mixed method approach is used to research: what impact does the intervention have on participants' motivation, engagement, learning of mathematics and development of participants? Five schools in Portugal participated in the study, between December 2021 and March 2022, with 12 sessions, one session/week, 45 minutes. The sample: 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls, 2 with ASD and 5 with Dyscalculia. The average age is M=8.6 with SD=1.8. Prior to the intervention, the following instruments were applied: pre-tests of math skills, communication and social interaction, receptive and expressive language; Childhood Autism Rating Scale; a Battery Movement Assessment Battery for Children; questionnaire Technologies/Video Games and Questionnaire of Support Measures for Learning and Inclusion. During the intervention, an observation grid and alternative communication materials were used per session. A PC, the SADP, gymnasium/relaxation room with a chair, table and gym supplies. From the results, computers, tablets, and mobile phones are the most frequently used by children. GRID/ABC Autism, Bini ABC/Human Body, and Minecraft/Troll are video games often played by participants. One girl aged 12 explained to the researcher how to create worlds on Minecraft, which is an indicator that "good" video games could be beneficial for ASD. "I feel free to explore my imagination!"- she said. Most children expressed rich verbalizations about SADP: "I love it", "This game is interesting". As preliminary results children were motivated, participative, engaged with learning math, and able to co-create motor activities inspired by SADP challenges. The data analysis of the present study is in progress and will be presented.

Keywords: Special Education, Autism Spectrum Disorder, Dyscalculia, Children, Game-based learning

1. Introduction

1.1 The Concept of Disability and Policies for Inclusion

Foucault's (1974-75) discourse in Abnormal, on disability, focuses on the historical-political time from the Middle Ages to the beginning of the 20th century. It highlights the meanings of segregation or exclusion of people with disabilities. It refers that in this historical period, the discourse of the political, medical and judicial power of abnormality was characterized as "grotesque" or "ubuesque". The speech was based on the assumption of disqualification of the subject.

The United Nations (UN) estimates that about 10% of the world's population lives with some type of disability. According to the Directorate General of Health (2015), the health of the Portuguese in terms of years of life lost as a result of problems of health, disability or death are as follows: non-communicable diseases 85%, injuries 9%, other 6%. According to the World Health Organization (2021), the commitment to "leave no one behind" and "to ensure healthy lives and promote well-being for all at all ages'', represents the global intention of the 2030 Agenda of ONU Sustainable Development. Reducing inequality and ensuring inclusive quality education is one of the goals of the World Health Organization. According to the practical guide from the National Institute of Rehabilitation (2019), around 11% of people residing in Portugal have some type of physical, intellectual or sensory limitation. The Constitution of the Portuguese Republic (CRP) establishes in Article 26(1) that "the rights to personal identity, personality development, civil capacity, citizenship, good name and reputation, image, word, to the privacy of private and family life and to legal protection against any form of discrimination". It enshrines in Article 13, the Principle of Equality, determining that all citizens are equal before the law, and no person can be discriminated against according to their condition. In 2009, Portugal ratified the Convention on the Rights of Persons with Disabilities and its optional protocol, which aims to "promote, protect and guarantee the human rights and fundamental freedoms of persons with disabilities, promoting respect for their inherent dignity and recognizing its self-determination". The National Institute of Rehabilitation, I.P. (INR, IP) is the public body whose mission is to ensure the planning, execution and coordination of national. In 2018, with the publication of Decree-Law no. 54/2018, the concept that it is necessary to "categorize" in order to intervene was abandoned, as it was recognized that the curriculum and student learning are at the center of school activity.

1.2 Children with Autism Spectrum Disorder (ASD) and Dyscalculia

Autism Spectrum Disorder (ASD) represents a disorder in human development with an impact on social interaction, verbal and non-verbal communication and symbolic play (Monteiro, Pimenta, Pereira, & Roesler, 2017). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2014)describes three levels of PEA with different support needs (Level 1 – Support; Level 2 – Substantial support; Level 3 – Very substantial support) in terms of social communication and restricted and repetitive behaviors. In the DSM-5, dyscalculia, is described as a coding within the specific learning disorder: "impaired in mathematics" (p.315.1). It exposes four areas in which difficulties arise: number sense; memorization of numerical facts; accuracy or fluency in calculation and accuracy in mathematical reasoning.

According to Villar (2017), the work developed by Ohlweiler (2016) indicates that learning is a process of acquisition and conservation and that, in the face of stimuli and experiences, brain changes occur in the Central Nervous System (CNS). The school has a key role in bringing the child closer to Mathematics, enabling their motivation to explore the process of mathematical knowledge, and stimulating the action-reflection-action and cognitive process (Borges, 2015). Following this thought, psychomotricity emerges in the present study. Psychomotricity was constituted in the educational context as a new psycho-pedagogical perspective. It has a multidisciplinary foundation and has a fundamental and essential place in perceptual-motor education, in the global education of the child (Fonseca, 1976).The General Directorate of Education and Science Statistics (DGEEC) estimates that in Portugal between the academic years 2016/2017 and 2017/2018, the number of students attending Structured Teaching Units for the education of students with ASD registered an increase of 9%, mostly in basic education.

1.3 Games and Learning

According to (Probst, 2017) special education communities have not valued the impact of digital media use on special education students, namely those with (ASD) and EBD. Videogames have played an increasingly important role in our society, whether as a leisure activity or applied to education and rehabilitation. With previously defined learning objectives, video games can be integrated into the educational process in different ways, either by game creation or by using commercial games (Gee, 2007; Choi, Shin, Ryu, Jung, Kim and Park, 2020). For Salen & Zimmerman (2010) there is an important distinction between videogames aimed at learning/research and learning obtained through commercial games. Young people use play as a medium where they can develop adaptive behaviors (Pellegrini, Dupuis, Smith, 2007). Learning strategies based on digital games have shown more significant effects than traditional approaches, namely expository ones, thus allowing higher and more effective learning gains (Sousa & Costa, 2018). For (Sousa & Costa, 2018) videogames are considered an engaging medium, they can create meaningful learning experiences, with immediate and concrete feedback, performance before competence, with optimal levels of challenge and frustration, while failure is used as a motivational tool (Gee, 2007; Granic, Lobel, & Engels, 2014).

The research proposed here seeks to explore the potential of games as facilitators of mathematics learning and promoters of global, communicational, relational, and social psychomotor development in children with ASD and/or dyscalculia, in Basic Education. The digital game "Space adventure: Defend the planet!", created within the scope of the research project GBL4deaf, is used in the present investigation as a starting point for carrying out a psychomotor intervention with children with ASD and/or dyscalculia focused on the development of math competences. The main question of this investigation is: what is the impact of games on the teaching-learning process of mathematics, as well as on the global psychomotor, relational, communicational and social interaction development in children with ASD and/or dyscalculia in basic education in Portugal? The specific questions are: a) What are the cognitive and learning gains in the process mediated by the game "Space adventure: Defend the planet!"? b) What differences will there be in terms of motivation and engagement? c) What are the existing differences in the relationship between the game experience factors and the learning and performance of mathematics by psychomotor representation in children with ASD and/or dyscalculia? d) What differences will exist in terms of global psychomotor development? e) What differences will exist in terms of language, communication and social interaction? f) What is the correlation between the game experience, cognitive, learning and communication gains in the mediated process?

2. Method

A mixed method approach has been used. The quantitative investigation will focus on the documented functions of cognition, measured by non-verbal scales. Qualitative measures will document engagement and motivation with the "game" and psychomotor intervention activities. The evaluation of the gaming experience will allow

documenting variables related to the factors that constitute it: engagement/involvement, flow, immersion, presence and challenge. Direct observation, interviews, questionnaires, observation grids, psychomotor assessment, and application of validated scales to assess the game experience are part of the applied methodology. Mediators of learning and of verbal and non-verbal communication were adopted. Direct observation and the application of scales to assess the game experience are part of the methodology applied to obtain data, based on the main research question. The data obtained will be compared, in the Baseline and Endline evaluation, of the same experimental group, using statistical tests to compare populations from paired samples or repeated measurements (Maroco, 2007, p.269). The game experience performed and developed by the students will be analyzed through quantitative and qualitative data, together with the data of the Endline learning results, by the correlation coefficients. One of the aims is to quantify the intensity and direction of the association between several variables (Maroco, 2007, p.42). The quantitative data obtained in the experimental group in the final intervention will be compared through statistical tests to compare results through independent samples, achieving a quasi-experimental approach (Peng & Ziskin, 2008). Qualitative data obtained in the experimental groups (game, digital/psychomotor intervention) will also be evaluated, by direct observation of students with ASD and/or dyscalculia. They will be analyzed using content analysis methodologies, to systematize and quantify the content obtained (Drisko & Maschi, 2016).

2.1 Student sample

The sampling is for convenience, resulting from the professional relationship of the Special Education and Rehabilitation Technique with the Resource Center for Inclusion, which operates in the Group of Schools from which the sample was taken. The sample: 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls, 2 with ASD and 5 with Dyscalculia. The age range of the sample is between 5-10 and 15-16 years old. The mean age is M=8.6 with SD=1.8. The group(s) of students representing the case study, with ASD and/or dyscalculia, attends the Basic Education (1st, 2nd and 3rd Cycle) of the Cluster of Sample Schools. Students are distributed across 5 schools. The Frequency of Basic Education is divided between the 1st, 2nd, 3rd, 4th, 6th and 7th years.

Table 1:-Sample representation by: age, school and year of basic education

Ages	Percentage %	School	Percentage %	Frequency of Basic Education	Percentage %
5-6	15,8%	E001	5,3%	1st Year	21,1%
7-8	42,1%	E002	15,8%	2nd Year	10,5%
9-10	26,3%	E003	10,5%	3rd Year	26,3%
15-16	15,8%	E004	52,6%	4th Year	26,3%
		E005	15,8%	6th Year	5,3 %
				7th Year	10,5%

Data for the (2016/2017) school cluster academic year indicate that at the level of teaching and non-teaching staff, there were 165 teachers, of which 45 were in the 1st Cycle of Basic Education and 85 in the 2nd and 3rd Cycle of Basic Education, with only 12 special education teachers.

2.2 Materials and Instruments

2.2.1 The Videogame "Space adventure: Defend the planet!"

According to (Marcelino, L., Costa, C., Neves, J. C., Melo, A., & Soares, F. M., 2020), the videogame "Space adventure: Defend the planet!": is an educational game in the field of mathematics for use in formal and informal learning contexts, developed within the scope of the GBL4deaf – Game-based Learning for Deaf Students project [PTDC/COM-CSS/32022/2017]. The player must use math skills to solve four challenges in order to build a space base. Each challenge consists of three levels of difficulty, designed to provide the player with the use of mathematical knowledge. The player is rewarded with the resources needed to build and upgrade their space base. Challenge 1 consists of an addition and subtraction puzzle, where the player must add or remove particles from an atom to obtain resources that allow him to move forward. In Challenge 2, there are multiplication and division tasks, where the player must decide the number of cars needed to transport the produced pulleys. It must also determine the total amount to be made in each round, using multiplication reasoning.

For the present study, only two challenges will be evaluated (1 and 2), a decision taken into account the selected population and its characteristics. The evaluation of the students will be carried out by direct observation at two different moments (initial and final) with a record of the student's performance in the two challenges.

Additionally, the material used in the fieldwork was: gamer computer; chairs; support desk; 1 room board; diverse pedagogical material used by the researcher in psychomotricity sessions and to complement the digital game (balls, wooden pieces; pieces, pictures, puzzles, among others).

2.2.2 Instruments

For the development of the present study, the following assessment instruments were used: 1) CARS Rating Scale (Childhood Autism Rating Scale); 2) Pre-test of mathematical skills: Diagnostic sheet (1st, 2nd, 3rd and 4th) year school manuals, respectively; 3) Pre-test of mathematical skills (2nd and 3rd cycle): instrument by the GBL4deaf project - Game-based Learning for Deaf Students; 4) Pre-test of Communication and Social Interaction and Receptive and Expressive Language; 5) Battery M-ABC-2 (Movement Assessment Battery for Children – 2nd Ed.), using Band 2 (7 to 10 years old) and Band 3 (11 to 16 years old); 6) An observation and recording grid of sessions; 7) Assessment Questionnaire for Measures to Support Learning and Inclusion; 8) Assessment Questionnaire for Educational and Playful Technologies and Digital Games.

2.3 Procedure

Permission to carry out this research work was requested from the School Cluster, which was approved at a meeting of the Pedagogical Council. The preparation of the intervention took place from October to November 2021. Data from students with ASD and/or dyscalculia were collected from the Pedagogical Technical Report, among the head teachers of the class, special education teachers and non-teaching staff. Pre-tests were applied: mathematical skills, communication and social interaction and receptive and expressive language. The assessment of children's movement was also applied using the M-ABC-2 Battery (Movement Assessment Battery for Children – 2nd Ed, 2007) and the CARS Assessment Scale (Childhood Autism Rating Scale) to assess the level of autism. All questions were read aloud, individually. When necessary, in the case of non-verbal students, alternative communication was used. In November 2021, two experimental sessions were held: the first corresponded to the presentation of the digital game, where students explored the game; second session corresponded to the experience of the digital game with transposition to a psychomotor game (psychomotricity), with the material available in each school. Alternative communication tables were used, constituting an element that facilitates communication and learning. This session was important it worked on the anticipation and mental organization of the following sessions.

Direct and individual observation of the students was carried out by only one evaluator, the Technique of Special Education and Rehabilitation, the researcher of the present study. It was a participant observation. The teaching/learning and observation sessions took place once a week, with a total duration of 45 minutes (30 minutes correspond to effective practice (15`videogame + 15`psychomotricity) and 15 minutes correspond to the presentation/introduction period of the session and necessary transition moment between the part of the digital game session, for the psychomotricity session that took place in the relaxation room or in the gym with work carried out, mostly on the floor. The sessions were carried out in a gym context or in a relaxation room context, based on the conditions of each school. A total of 12 sessions were held between December 2021 and March 2022.

While quantitative research will focus on the cognition functions documented as fundamental in the process of acquiring competences in the field of mathematics, qualitative measures, measured through non-verbal scales, sought to document children's engagement, motivation, engagement with the " game" and psychomotor intervention activities. The evaluation of the game experience (game experience) aims to document variables related to the factors that constitute it, namely: engagement/involvement, flow, immersion, presence and challenge (Brokmayer et al., 2009; IJsselsteijn, de Kort, & Poels, 2013). As this is an ongoing investigation, within the scope of the researcher's doctoral thesis, this study presents preliminary results.

3. Results

In total, 34 different strategies were adopted during the 12 sessions. Here we will present only the strategies corresponding to the sessions presented below. Ten (10) of those were used: in the sessions presented below: **In Figure 2 and 3**: work carried out on the floor; music chosen by the student's; Positive communication (you can do it, go ahead, very well, among others); **Figure 4 and 5:** simple material that I used daily in a school context; puzzle pieces; transition from a digital game to a motor task on a table; **Figure 6 and 7**: giving time to organize thoughts and perform the task; using different material sizes; different colors and different shapes.

This Action Research project involves 19 children and young people who attend Basic Education (1st, 2nd and 3rd cycle) of regular education, with ASD and/or dyscalculia. The sample is heterogeneous, with 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls 2 with ASD and 5 with Dyscalculia. The mean age is M=8.6 with SD=1.8. The age range of the sample is between 5-10 and 15-16 years old.

In the sample of 19: 84,2% (16) of children have a computer and among them 52,6% (10) play video games on PC. 73,7% (14) have a tablet and 68,4% (13) of children play video games on it. In regards to having a smartphone, 26,3% (5) of children reported to have one, but 47,4% (9) children use it for playing video games, which means they play on other people's mobile phones. Table 2 shows the videogames most played by students on Computer, Tablet and Mobile.

Table 2: Number of videogames by technology

Used technology	**Number of videogames played**	**Most played games/ Percentage %**
Computer	**18**	Grid 60% (6); Animal sounds 50% (5); Draw Shapes 50%(5); ABC Frog 50% (5); Gcompris 40% (4); ABC Autism40% (4).
Tablet	**23**	Human Body 46,2% (6); Animal Farm for Kids 38,5% (5); Bini ABC 38,5% (5); Word shape 38,5% (5); Sonic the Hedgehog 38,5% (5); ABC Autism 30,8% (4); Gcompris 30,8% (4); Word Adventure 30,8% (4); Coloring Book 30,8% (4).
Mobile Phone	**20**	Minecraft 44,4% (5); Troll Master 44,4% (4); Merge Home 33,3% (3); Mini Market 33,3% (3).

Of the 12 game sessions carried out, 3 case studies are analyzed, with 3 children and their respective activities in a single session.

Game situation - challenge 1, level 1: positive and negative particle cannons are used so that the player can fire, one at a time, and take the black triangle to the green circle, thus obtaining metals and resources necessary to progress in the game. Figure 1 shows a successful situation. If the player fails, he can continue to play without any penalty.



Figure 1: The player obtained 1 metal after achieving the goal of reaching 2

Description: Student 9 (A009); School (E004); (1st year); 6 years



Figure 2: addition math symbol

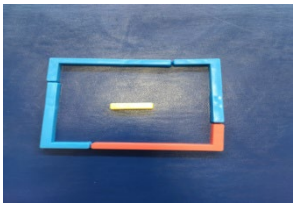


Figure 3: subtraction math symbol

Figure 2 and 3 - Session 1-Challenge 1/Level 1: In the digital game there are two particle cannons, one shoots negative particles (subtraction) and the other shoots positive particles (addition).The researcher placed numbers and pieces of different colors and geometric shapes on the rug. The child was asked to create the mathematical symbol for addition (+) and for subtraction (-), which appears on the cannons. He could select, up to 3 colors.

Results obtained: The child understood the verbal instruction of accomplishment and selected three different colors, as requested “I like these colors”. Selected different colors of symbols from the game; A good spatial organization was observed, and has commented: “I am making a square with large pieces and the sign is small. Poor little thing". The recognition and realization of geometric shapes and mathematical symbols present in the digital game were visible, with good time management and good body posture. He showed pleasure, good interaction with the technique and presented a fluent speech.

Description: Student 2 (A002); School (E003); (3rd year); 8 years

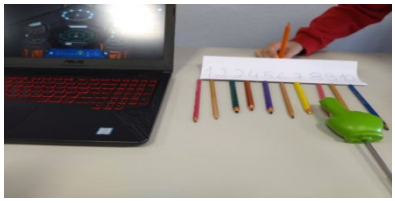


Figure 4: Digital game: challenge 1

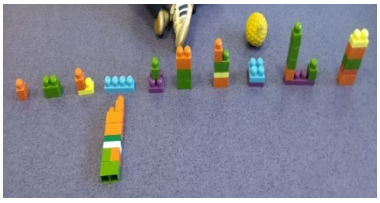


Figure 5: Psychomotor game: count up/down

Figure 4 and 5 - Session 6- Challenge 1/Level 1: The number line given by the game indicates the numbers from 1 to 10. The triangle (bottom line of the line) indicates the amount that the game gives us and the green circle (upper line of the straight line), indicates the value intended as a result. When performing the digital game, the student presented specific difficulties in reasoning and in understanding the increasing and decreasing sense of numbers, on the number line. To better perform the mathematical operation, he got up and with the help of the material seen in fig.4. He positioned himself behind the straight line (something he could not do in the video game) and was able to tell if the operation was addition or subtraction (there are 8, but the intended result is 6), and did on the floor, as seen in Fig.5, the number line using puzzle pieces with an indication of the value given by the game, in another calculation, represented by the puzzle pyramid, and the intended value as the result indicated by the yellow ball.

Results obtained: The student successfully completed the task. He delivered a simple but understandable speech; presented atypical motor agitation and deficit in attention and concentration “today I am tired, I did not sleep well”; Difficulty in carrying out the mathematical calculations, it was necessary to do reinforcement on the table, with motor experience, to understand the increasing and decreasing direction and thus carry out the calculation; He managed to transpose the number line correctly from 1 to 10.

Description: Student 4 (A004); School 4 (E004); (4th year); nine years old

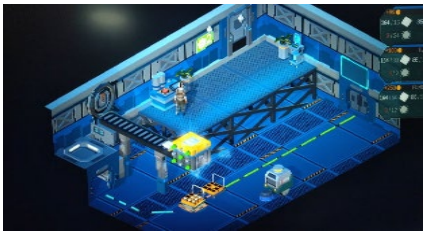


Figure 6: Digital game: Challenge 2



Figure 7: Psychomotor game: multiplication

Figure 6 and 7 - Session 8 - Challenge 2**:** the player heads to the machine that will release the metals. Upon release, the metals fall to the mat and trigger a number of lights. After observing the value, the calculation can be by multiplication (ex: 2 metals x 2 lights=4) or addition (2 metals, each one is worth two lights 2+2=4). Then the student must select how many carts he will use (ex: for result 4 the student can choose 4 carts that only carry 1 material or 2 carts with a capacity for 2. After selection, the carts move forward and collect the sprockets in the present case 4. The pieces are transported out of the metallurgy and the player moves on to the next challenge, which is not used in this research project. After playing challenge 2, the child was asked to replicate an account that he had made during the game session on the computer. The student selected the material and set up the route by himself and without assistance. He opted for a simple multiplication operation 2x2=4. As can be seen in Fig. 7, the student creatively simulated the game and was efficient in choosing the carts, having opted for 2 cars of 2 instead of 4 cars of 1.

The student successfully completed the task and was able to transform the digital game in a psychomotor game. He was very motivated and committed, saying that “I like this game. It's very cute”; He walked the route as if he were “inside” the digital game, imagining where the machine in digital game is located to activate the challenge and adopting the operator's movement. Later on the student walked into “his game” space to operate the account, moving correctly and freely.

4. Discussion

From the results obtained from the psychomotricity sessions presented, at the level of verbal communication, there was a variety of verbalizations rich in detail, for example: "We should have more games like this". There were some difficulties in terms of issues related to the body, reasoning and logic, organization and planning, memory, concentration and attention, stereotypes, mathematical concepts of subtraction and multiplication and communication in 3 cases of the sample. The digital game contributed in a very positive way to the dynamization of psychomotricity sessions. Realizing the variety of games and exercises that it was possible to carry out based on the digital game was really interesting and challenging both for the students and for the TSEER. This constituted an excellent pedagogical tool, which allowed to enhance the creativity of the TSEER and of the students. It was an element that enhanced and facilitated interdisciplinarity, essential for the integration and inclusion of children with ASD and/or dyscalculia. The individualized one-to-one work also represented a positive and facilitating element of learning. The psychomotricity sessions also proved to be an excellent complement to the game. Observing students' freedom of movement, communication, thinking, reasoning, relationships, and participation was exciting. The adoption of differentiated pedagogical practices is a good way to support them in learning and progress.

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Who Stole the Book of Kells? Description and Player Evaluation of a Cryptography Game for Primary School Students

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Abstract: Several studies suggest the need to develop technology skills from a young age. The development of computational thinking enhances multidisciplinary abilities, such as abstracting and decomposing a problem into smaller parts to find a solution. Among various tools, educational games can be implemented to efficiently stimulate the development of technology skills in primary school students. The current paper describes an educational game designed to motivate players to learn and reflect on cryptography, a collection of computer science techniques adopted for data protection. *The Code of Kells* is a mystery game that aims to support the development of computational thinking and maths abilities for primary school students. In this collaborative game, 10-12 years old players use cryptography techniques to discover who stole the Book of Kells – an ancient manuscript kept in the Trinity College Library in Ireland. To identify the criminal's identity, the players should work on teams and follow a map of Dublin city to collect encrypted clues hidden in popular locations, such as Phoenix Park and Dublin Castle. The participants should follow guidelines provided by a cipher sheet that illustrates cryptography techniques such as Caesar's Cipher, Polybius Cipher, Pigpen Cipher and the Morse Code. Each clue leads the player closer to the revelation of who stole the book of Kells. In this study, 80 primary school children (10-11 years old) evaluated *The Code of Kells* by sharing their experience through an adapted version of the Game Experience Questionnaire (GEQ). Nine dimensions of the questionnaire were assessed considering children's previous mathematics and literacy scores, besides their levels of maths anxiety. Results suggest that children with higher mathematics performance positively perceived the game and found it challenging. However, results also indicate that maths high achievers students also felt tense while playing. Students with high levels of maths anxiety perceived the game as a sensory and imaginative immersive activity.

Keywords: game-based learning, computational thinking, cryptography, primary school, ciphers.

1. Introduction

In the current digital 21st-century world context, even those who do not intend to work as computer scientists might be required to develop some level of digital literacy (Wing, 2006). Therefore, schools have been attempting to embrace a curriculum that includes the development of computational thinking skills, a set of human understanding and perceptions of the process computers use to solve problems (Weintrop *et al.*, 2016). According to Wing (2008), computational thinking goes beyond only being able to write a computer program but includes using abstraction and decomposition to tackle complex problems, and should its development motivated since the early years of education. Previous research suggests that teaching cryptography, a collection of techniques used for data protection, can foster children's computational thinking. This can be due to cryptography promoting a natural and meaningful way of helping students build up problem-solving skills and strategic thinking (Koblitz, 1997). Cryptography learning can also increase the ability to abstract and decompose a problem into smaller parts to quickly find a solution – skills shared with other areas of education, such as mathematics (Klembalski, 2009).

Among various tools, educational games can be used to support computational thinking skills and cryptography learning in primary school. Some advantages of using games include promoting cooperation, learning engagement, and the development of problem-solving strategies (Baek, 2010) and stimulating collaborative work among players (Sun, Chen and Chu, 2018). A variety of skills can also be obtained through games for technology and maths education and communication, such as problem-solving and critical thinking (Checa-Romero, 2016).

The current paper describes the development and evaluation of a cryptography educational game designed to motivate players to learn and reflect on the power of ciphers in data protection. The game is followed by a narrative that includes historical aspects, supporting gameplay immersion and interdisciplinary learning.

2. Research Background

The current paper describes the development and evaluation of a cryptography mystery game designed for primary school children (8-12 years old). This section attempts to shed light on the research background that supports using this type of learning tool to support mathematics learning and the development of skills such as computational thinking.

2.1 Cryptography in primary school

Cryptography is the set of techniques used to protect private information, especially by encrypting and decrypting messages that do not allow third-parties to intercept them (Griffiths, 2015). Besides the practical applications on data security, cryptography is also considered a rewarding way to introduce mathematics and computer science topics into the classroom, besides stimulating pupils' problem-solving skills (Borelli *et al.*, 2002). While solving cryptography puzzles, students need to use several interdisciplinary abilities and personal experiences, making the challenge highly engaging (Kaur, 2008). Due to the challenge and fun embedded in puzzle-solving, children's interest in riddles appears even in the preschool-age (Azhmukhamedov, Kuznetsova and Vybornova, 2019). This level of engagement can support the development of computational thinking skills.

2.2 Cryptography and storytelling

The use of secret codes to protect information dates from way before digital technology became part of our daily lives – for instance, ciphers can already be found in the Bible (Borelli, 2002). In a book about the history of cryptography, Simon Singh describes how Mary, Queen of Scots, was beheaded after her plans of killing Queen Elizabeth were discovered (Singh, 1999). The plan details were coded using a substitution cipher, which made the text meaningless for those who did not know how the content was encrypted. However, they were intercepted and decrypted by an England spymaster, leading to the execution of the Scottish queen. This episode took place in 1586, and still nowadays, with some additional complexity, substitution ciphers can be used in data protection. The history of cryptography allows teaching ciphers with the aid of storytelling. This powerful tool can make complex topics more meaningful by providing a context, allowing children to connect the concepts learned to other areas of childhood (Casey, Kersh and Young, 2004). An essential component of historical approach-based education is the immersive feature of learning through a narrative. Children tend to learn better when immersed in a story (Manwell and Sullivan, 2013), and games are a vital tool to provide this immersive feeling. An engaging narrative is one of the elements that can make a game immersive, especially when it shows just what is needed at a given time without presenting all possible characteristics of the game at once (Mendonça, Mustaro and Mackenzie, 2012).

3. Methodology

The present paper provides the description and classroom evaluation of a cryptography educational game created for 8-12 years old primary school students. The evaluation includes a pre-gameplay phase when the teacher shares the students' maths and literacy scores to inform the researchers about their previous knowledge in those fields. During the pre-gameplay, researchers also use psychometric scales to collect students' levels of maths anxiety, a collection of negative feelings associated with activities that involve the manipulation of numbers and calculations (Jansen *et al.*, 2013; Caviola *et al.*, 2017). Then, as the topic can be new to many children, an introductory cryptography workshop takes place, where the researcher explains some ciphers. The workshop is followed by a team-based gameplay session where the students play a cryptography mystery game. Students self-report their playing experience using a validated questionnaire during a post-gameplay session. The following sections describe each phase of the classroom evaluation and detail how the user-testing data is analysed.

3.1 Cryptography introductory workshop

The evaluation of the Code of Kells takes place in a primary school classroom. The session should last one hour and be guided by a researcher, with the possible support of the teacher. The session starts with a 15-minutes cryptography introductory workshop. The initial minutes involve the history and the importance of developing ciphers, where the researcher introduces examples of secret messaging used before the adoption of cryptography. One example given to the students relates to the Ancient Chinese, who used to send secret messages by writing those on a piece of silk (Singh, 1999). The silk would then be scrunched in a ball covered with wax so it could be swallowed by a messenger, who would carry it in his stomach to the destination. The following minutes of the workshop includes presenting each cipher, demonstrating how they work, and inviting children to try to use the ciphers to read secret messages.

3.2 Gameplay

The game described and evaluated in the present paper is entitled *The Code of Kells*, a team-based multiplayer game where students are invited to solve a mystery. The game has a collaborative element, and all the players should work in teams. Using cryptography techniques such as Caesar's Cipher, Polybius Cipher, Pigpen Cipher and Morse Code, the teams can work on the puzzles that lead to solving the mystery. The game can be adapted for different ages and gameplay durations by including or excluding puzzles and ciphers. Table 1 summarises the different components of the game and is followed by their descriptions.

Table 1 The Code of Kells game components.

The Code of Kells – Game components		
Material	**Mechanics and Rules**	**Game ambiance**
- Digital slides - Game sheet - Cipher's sheet - Map of Dublin - Blank papers - Pencils	Players should get together in teams and solve encrypted puzzles. The first team to solve each puzzle is awarded. The team who solved more puzzles wins the game.	The narrative takes place in the Trinity College Dublin library and describes the theft of the Book of Kells

For this pilot study, the Code of Kells is presented in digital slides projected to the students. Before playing, students are invited to join their classmates in teams according to affinity. Each team receives a game sheet where their names and team name can be inserted, a map of Dublin city, and a cipher's sheet containing short explanations about each cipher used in the game. Teams are also provided with blank sheets of paper and pencils to be used to elaborate their responses to the puzzles.

The game narrative takes place in Dublin, capital of Ireland, more specifically at the Trinity College Library, the largest one in the country. This library holds the book of Kells, a manuscript gospel book written in Latin and dated from 800 years before current era (Bioletti *et al.*, 2009). The story of the game starts by describing a member of the staff nervously calling a team of detectives to communicate a tragedy: the book of Kells was stolen and someone needs to find it. The players are then invited to join this man in the library, who provides a piece of paper left by the criminal, containing a weird collection of letters and a key number (Figure 2).

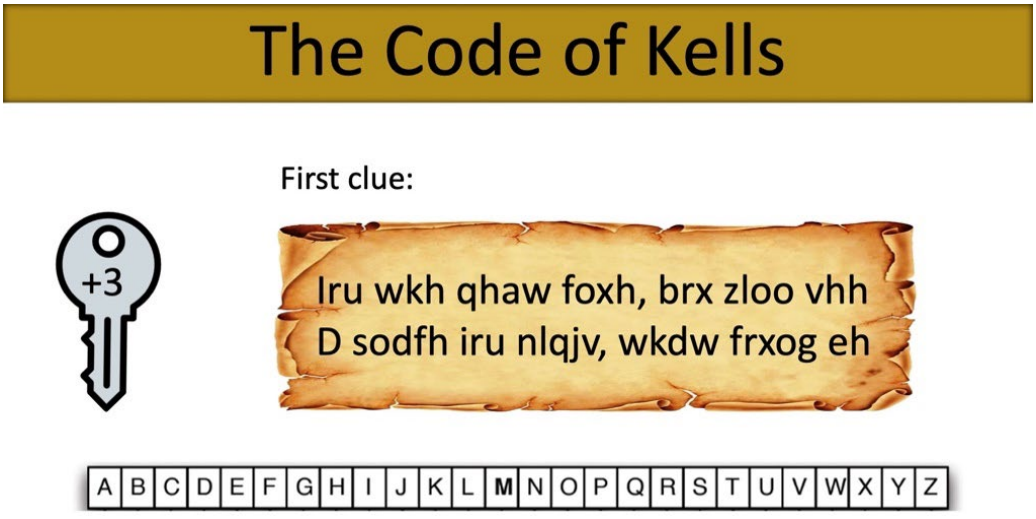


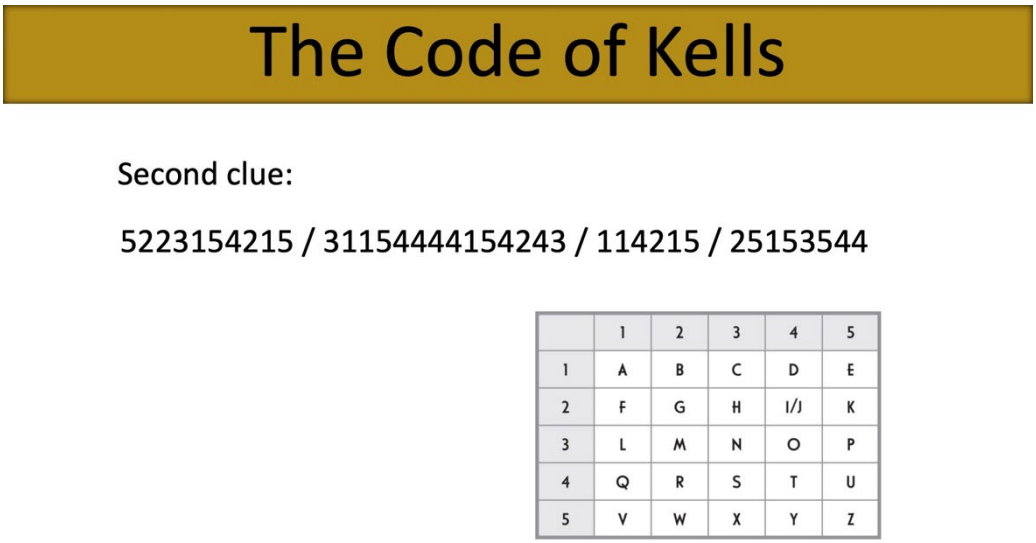
Figure 1: First clue left by the criminal in The Code of Kells.

Based on the cryptography introductory workshop, the players should be able to identify that the message was encrypted using Caesar's Cipher, where each letter is shifted a number of letters to the right (when a positive key number is used for encryption) or to the left (when a negative key number is used for encryption) in the alphabet. The key number on the slide represents the number of letters to be shifted. Using the cipher's sheet, the players decipher the message, which results in a riddle such as the following:

For the next clue, you will see

A place for kings, that could be

After deciphering the riddle, the team of players should check the map and try to identify to which place that clue leads – in the aforementioned case, the clue leads to the Dublin Castle. The first team to guess the next place to be visited receives a sticker on their Game sheet, and all teams move to the Dublin Castle. The narrative unfolds by inviting the teams to check the castle' walls only to find their next clue: a collection of numbers to be deciphered using the Polybius Cipher (Figure 2).



	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I/J	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

Figure 2*:* Second clue left by the criminal in The Code of Kells.

The game follows with the teams of players collecting and deciphering new riddles, and visiting different places that are relevant to the history of Dublin city. Finally, the teams reach the president of Ireland's house, where the president's dog hold the final clue that results in the following riddle:

A green jacket
Covers his arms
Do not ever steal
His Lucky Charms

The players then discover the criminal's identity: the Leprechaun, a fairy-like creature very popular in the Irish mythology.

3.3 Data collection

The current study is part of a research project that aims to evaluate the potential of games on maths learning. In this project, students are identified by random IDs to guarantee data anonymisation, so researchers have no access to students' real names. In the pre-gameplay phase, two main sets of data are collected. First, teachers provide details about students' previous grades on standardised tests for mathematics and literacy, ranging from 1 to 10. Later, researchers meet the students and invite them to answer the Abbreviated Mathematics Anxiety Scale (mAMAS), a scale developed and validated by (Carey *et al.*, 2017) to assess maths anxiety in primary school children. The scale consists of a self-report questionnaire with nine items. Children use a 5-point Likert scale to indicate how anxious they feel when dealing with maths situations, where one is equal to low anxiety, and five equals high anxiety. The higher the final score, the more anxious the child is. The minimum score is 9, resulting in a low level of maths anxiety, and the maximum score is 45, which results from a high level of maths anxiety. Students are then invited to share their experiences while playing the Code of Kells in the post-gameplay phase. This occurs by answering a modified version of the Game Experience Questionnaire (GEQ) (IJsselsteijn, de Kort and Poels, 2013), a tool developed to evaluate the players' perceptions considering several dimensions. Questions describing the player's experience while playing the game are presented, and the respondent should select the level of agreement (from 1, do not agree at all, to 5, extremely agree) As the original questionnaire is not designed for primary school children, an adapted version was adopted in this study. Table 2 shows the GEQ

questions selected for the adapted version, besides what measures of game experience they measure. Some questions had their language simplified to adapt to the audience's level of literacy.

Table 2*:* Selected questions and dimensions included in the adapted version of the GEQ

User-experience dimension	Question (adapted from GEQ)
Behavioural Involvement	I felt important for my team
Challenge	I thought it was hard
	I felt pressured
	I felt challenged
	I had to put a lot of effort into it
Competence	I felt clever
	I was good at it
Negative affect	It gave me a bad mood
	I thought about other things while playing
	I felt bored
Positive affect	I felt content
Psychological Involvement - Empathy	I felt connected to my team
	I enjoyed working on a group
Psychological Involvement – Negative Feelings	I felt jealous about the other members on my team
Sensory and Imaginative Immersion	I was interested in the game's story
Tension/Annoyance	I felt annoyed
	I felt frustrated

3.4 Data analysis

The results collected from the data provided by the teachers and the mAMAS questionnaire are manually inputted into a password-protected digital database. The analysis is carried out through statistics techniques using the software IBM SPSS Statistics 21. The statistical analysis considers relevant tests for descriptive statistics, frequencies, and statistical significance to evaluate what individual aspects influence students' experience while playing *The Code of Kells* game considering the different dimensions of the adapted GEQ.

4. Results

This section describes the study's results considering the descriptive statistics and inferential analysis.

4.1 Descriptive statistics

The participants were recruited through the larger project that this research is part of. Researchers contacted the school and informed them about the user-testing procedures. Once the schools agreed to participate in the research project, parents' consent and students' assent documents were provided. The researchers then visited the school to collect data about students' levels of maths anxiety and previous scores in maths and literacy. Later, one of the researchers visited the school for the evaluation of *The Code of Kells*. The present paper describes a session that took place in five classrooms (four 4th class and one 5th class) from two schools located in south Dublin city. A total of 80 students participated in the experiment. Two of the participant classrooms were part of a girls-only school, resulting in a sample of 59 female students and 21 male students.

The evaluation session took place during an one-hour visit to each classroom, where students participated of the cryptography introductory workshop, followed by the Code of Kells gameplay session, and a 10 minutes session when students were invited to answer the adapted GEQ. During the gameplay, the participants were grouped in teams by affinity, but were also allowed to move around the classroom, getting closer to the smart board in case they wanted to have a better look at the game puzzles (Figure 3).

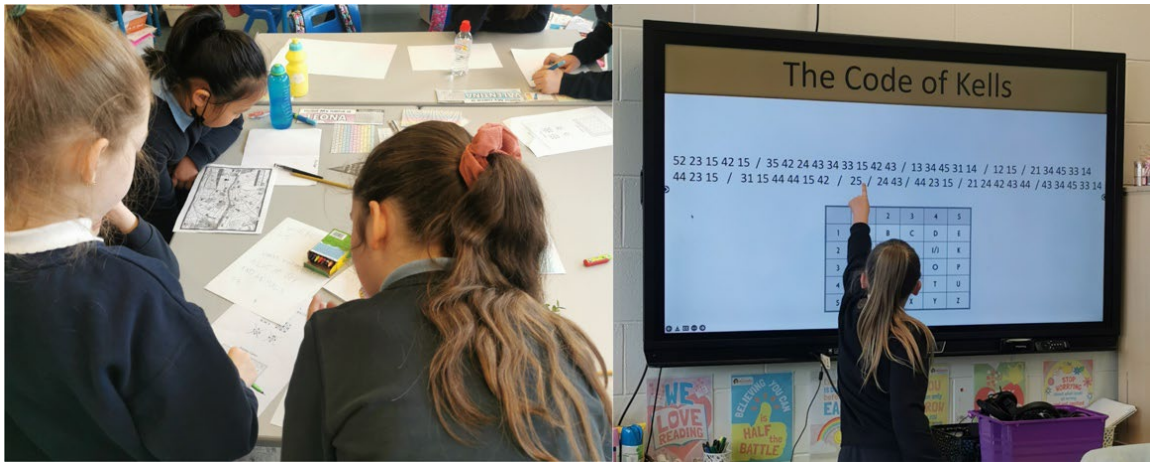


Figure 3*:* Classroom evaluation session of The Code of Kells.

Data cleaning was performed to remove users with missing values, resulting on the data analysis of a sample of 72 participants. Table 3 shows the means and standard deviations of the pre-gameplay individual metrics (mAMAS, literacy and maths scores), besides the means and standard deviation for each dimension of the adapted GEQ, applied during the post-gameplay phase. The dimensions with higher mean scores are, in descending order, Sensory and Imaginative Immersion (3.65) and Positive affect (3.31). Dimensions that represent a negative gameplay experience had low mean scores, such as Negative affect (1.30) and Psychological Involvement – Negative Feelings (1.49).

Metrics	Minimum	Maximum	Mean	Std. Deviation
Maths score	0	10	5.49	2.29
Literacy score	0	10	4.86	1.83
mAMAS score	9	45	20.53	6.83
Positive affect	1	5	3.31	1.29
Sensory and Imaginative Immersion	1	5	3.65	1.13
Negative affect	1	5	1.30	0.72
Competence	1	5	2.69	1.31
Challenge	1	5	2.70	1.06
Tension/Annoyance	1	5	1.94	1.13
Psychological Involvement - Empathy	1	5	2.90	1.43
Psychological Involvement – Negative Feelings	1	5	1.49	0.99
Behavioural Involvement	1	5	3.22	1.44
Number of participants	72			

4.2 Inferential analysis

To understand what influences student's game experience while playing *The Code of Kells*, a Multivariate Analysis of Variance (MANOVA) was performed. For this analysis, three independent variables were considered: students' levels of maths anxiety, score of previous knowledge in maths, score of previous knowledge in literacy. The dependent variables considered in this study are the 9 components collected through the adapted GEQ modules: Positive affect, Sensory and Imaginative Immersion, Negative Affect, Competence, Challenge, Tension/Annoyance, Psychological Involvement – Empathy, Psychological Involvement – Negative Feelings, and Behavioural Involvement. Preliminary assumption testing was conducted with no serious violations noted. Assumption homogeneity of variance was tested by Levene's Test of Equality of Error Variances, and the assumption was met by the data ($p>.05$). Maths score had a statistically significant influence over three dimensions: Positive affect ($F(1, 68) = 7.9$, $p = .007$, partial eta squared = .104), Challenge ($F(1, 68) = 5$, $p < .05$, partial eta squared = .028), and Tension/Annoyance ($F(1, 68) = 9.6$, $p = .003$, partial eta squared = .124). The mAMAS score had a statistically significant influence over one dimension: Sensory and Imaginative Immersion ($F(1, 68) = 8.8$, $p = .004$, partial eta squared = .115).

The results suggest students with higher maths performance tend to have a more positive perception of *The Code of Kells*, and feel more challenged by the game. Furthermore, these students also feel higher levels of tension and annoyance when playing the game. Another suggested result is that students with higher level of

maths anxiety have higher levels of perception of *The Code of Kells* as a game that stimulates their sensory and imaginative sense of immersion.

5. Conclusions and discussion

The present study aimed to describe and evaluate users' perceptions of *The Code of Kells*, an educational cryptography game for primary school students. The responses to the adapted GEQ reveal students had a positive experience while playing the game, resulting in high scores on positive dimensions of the questionnaire. However, when analysing what individual metrics influence the user experience in the game, some specific results should be carefully considered. The outcomes suggest students with higher maths scores had a more positive perception of the game. That can be due to the high correlation between students' maths abilities and their computational thinking skills, as demonstrated by previous studies (Qian and Lehman, 2016; Kumar, 2019). In fact, researchers have already demonstrated that connections across the domains of mathematics and computing are made by students (Sand *et al.*, 2021), and tools similar to the game here evaluated might be useful to support students' development of computational skills. The same metrics of maths scores also had a significant impact on students perceptions of challenge. Although being over-challenged can discourage some students, high achievers tend to feel bored with regular school activities (Cleaver, 2007; Freedberg *et al.*, 2019), and might appreciate the extra challenge provided by elaborated puzzles (Reinhold *et al.*, 2020). Curiously, students with higher maths scores also scored higher for the dimension Tension/Annoyance. Further analysis should be conducted to better understand why those students felt tense while playing. One possibility is related to the high level of competition among the teams. Although competition in educational games can be beneficial in increasing student's engagement and motivation (Cheng *et al.*, 2009), competition can also negatively affect a student's self-efficacy beliefs, motivation, and performance (Bandura and Locke, 2003).

Another result to be highlighted is the correlation between high levels of maths anxiety and students' perception of *The Code of Kells* as a sensory and imaginative immersion experience. The storytelling component of the game might influence this perception, especially considering that narrative-based learning leads students to connect the concepts learned to the human experience (Hobbs and Davis, 2012), which can result in making abstract concepts more meaningful and less scary – a very valuable outcome for anxious students.

6. Future Work

The present study has some limitations as the data collection did not include specific questionnaires to evaluate the level of students' computational thinking or focus groups/interviews to retrieve qualitative information about the players' perceptions. In-depth future studies need to be carried out to better understand the potential of the Code of Kells in supporting mathematics and computer science learning. Focus groups will be conducted in the future with the aim of collecting detailed qualitative data of students' perceptions of the game. Furthermore, a digital version of the game is planned to collect game logs metrics, such as the strategies used to solve the puzzles, the time taken to work on them, and the number of attempts. In a digital version, the game could also be easily adapted to have a narrative taking place in other countries' famous libraries, allowing the extension of the interdisciplinary character of the game.

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A Reflective Game Design framework for Game-Based Learning

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Abstract: Reflective practice is the ability to revisit and reassess one's previous actions to engage intentionally in the process of learning. The concept of reflection leads from unconscious aspects of learning or experience to mindful awareness, giving an individual the power to absorb everyday experiences to make appropriate conscious choices. Digital games in game-based learning (GBL) offer interactive learning with authentic practice and a high retention rate. Digital games are also considered an immersive and safe medium of stealth learning with the freedom to identify, explore, fail, and then retry. Main game elements such as feedback in a user interface (UI), head-up displays (HUDs), maps, prompt messages, and social discourse are reflective in nature; therefore, by default, games are reflection machines and appropriate mediums for triggering and supporting reflective learning. However, despite reflective learning having the ability to improve teaching and learning experiences in a practical form, work dedicated to reflective design in GBL is still limited. Previous studies have incorporated reflective practices into a learning environment to improve the learning rate. These practices may vary over domains and yield different outcomes that are not converged yet. While current game design comprises all features that facilitate reflection "as a whole set", it misses individual reflection differences. However, getting maximum usage of the reflective nature of games with authentic learning content while maintaining the fun criteria can be challenging. Hence, a sound design methodology and guidelines are needed to assist the game designer in aiding effective learning with reflective practices. In this paper, our primary purpose is to align reflective learning practices with existing GBL approaches and then provide a framework to incorporate reflective learning practices into designing GBL. The intention is that this framework will help designers, educators, and researchers to design game-based learning experiences following reflective design practices.

Keywords: Reflective design, game design, game-based learning, reflective learning, framework, learning cycle

1. Introduction

Digital games have now become an important part of our society (Oblinger, 2004) and are particularly popular with children, adolescents, and young adults (Mumtaz, 2001). Thus, digital games play a vital role in people's lives outside school, by holding a particular attraction with fascination and provoking a deep sense of engagement in them (Facer et al., 2004).

In spring 2020, gaming quickly emerged as one of the most popular activities during the initial outbreak of the global COVID-19 pandemic as user engagement and spending surged between February and April of that year. Especially younger generations Gen Z and Millennials spent more time on gaming as the medium was a convenient way to spend time during the initial stay-at-home orders, lockdowns, and social distancing (Clement, 2021). Additionally, a study by Jaeger et al. (2020) showed that globally there was a permanent 21% increase in monthly spending by gamers, an 11% increase in time spent gaming, and a 40% increase in video game streaming during May and June 2020 versus pre-COVID-19 (Jaeger et al., 2020). Hence, digital games in are getting a double boost among youngsters.

Digital games have already been accepted as a suitable learning medium for education and training (Gee, 2004). Games and Learning Publishing Council published a survey on teaching with digital games which suggests that 55% of nearly 700 teachers have used games for students to play at least weekly (Takeuchi & Vaala, 2014). Serious games, Game-based learning (GBL), e-learning, and gamification have also been gaining much interest in academia and the fields of edutainment (Martens & Müller, 2017). All these concepts overlap and possess each other's elements. GBL is an active technique where game characteristics and principles (i.e., gamification, learning goals, pedagogical methods) are embedded within learning activities and yield a suitable medium for learning. According to Prensky, GBL can help ease and improve learning by making it exciting, thus supporting motivational gain with engagement in the student's learning (Prensky, 2003). In GBL, "Play" is a vital aspect because it enables learners to learn through connection and interpretation with their surroundings, i.e., physical and social worlds (Gee, 2004). GBL uses gaming technologies and techniques to create a fun, motivating, and interactive virtual learning environment that promotes situated experiential learning (Fotaris & Mastoras, 2019).

The rest of this paper is structured as follows; Section 2 discusses the Background and literature review, Section 3 presents the existing GBL framework and then proposes a new reflective design framework, and section 4 concludes the paper with future work.

2. Background and Literature Review

2.1 Reflective Learning

John Dewey introduced reflection in the thinking process and its effects on skill development (Dewey, 1933); furthermore, he explained reflection as an activity that includes revisiting and reassessing previous beliefs intentionally and proactively. The concept of reflection leads from unconscious aspects of learning or experience to mindful awareness, giving them the power to absorb everyday experiences to make appropriate conscious choices. Moreover, reflection refers to consideration or serious thought for individual reasoning (Sengers et al., 2005). It also allows individuals to apply and develop their knowledge and skills in a learning domain. The concept of "Critical reflection" plays a vital role in a person's freedom and quality of life. In acquiring a skill, reflective learning stages are shown in Figure 1 such as 1) Serious thought or consideration; 2) Reasoning; 3) Construction of understanding and planning; and 4) finally, Applying and developing knowledge learned skill. Hence, it allows an individual to apply and develop their knowledge and skills (Schon and DeSanctis, 1986). Critical reflection plays a vital role in both one's freedom and quality of life in society as a whole. Reflective learning varies from person to person; it does not come naturally as they usually need a reason, trigger or encouragement to reflect (Fleck and Fitzpatrick, 2010).

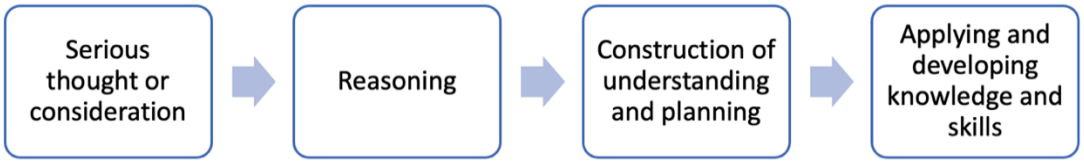


Figure 1: Learning Stages through Reflection

In a definition by Mezirow (1994), "*reflective learning is the social process of constructing a new or revised knowledge/interpretation of one's experience as a guide to action*". Reflective learning is related to behavioural change by rethinking an event or knowledge with the intent to re-organise it with creativity and/or to do something differently (Fleck and Fitzpatrick, 2010). This level of reflection can be achieved by revisiting an event by reflective and dialogic description while putting in a high level of thinking and, at the end, it becomes an integral part of human behaviour. Self-reflection encourages action, understanding, and co-learning, thus making reflective and critical learning a potentially significant guide (Gray, 2006). Furthermore, the process of *Reflection* can produce dramatic and sweeping changes in an individual (Allee, 1997).

2.2 Reflective Game Design

"Games are reflection machines" (Khaled, 2018)

According to Sengers et al. (2005), *"reflective design is comprised of design principles and approaches that lead designers to rethink the designing metaphors and values to encourage users to engage in the same practice with improved aptitude"*. Thus, reflective design practices assist both designers and learners in a continuing reflection in the development of technology with their relationship to personal life experiences. Over the last few years, reflection has become an essential part of interaction design in human-centred design, i.e., reflection within technology (Sengers et al., 2005) and reflective game design (Khaled, 2018).

Reflective game design offers new prospects for research, e.g., exploring how educational games are a suitable medium to facilitate reflection and how they can significantly influence users' learning outcomes and behavioural changes (Khaled, 2018). Digital games possess distinct traits of freedom (Klopfer et al., 2009), along with the element of fantasy and curiosity (Malone, 1980) that help promote stealth reflective learning. They can also encourage interactive learning, help to overcome disengagement and provide authentic practice (Kapp, 2013). Therefore, games are a suitable mechanism for triggering and supporting reflection in serious games. Khaled (2018) proposed a list of principles that emphasise design qualities in reflective design and discourage certain conventionally accepted design qualities.

In their systematic review, Shaheen et al. (2021) identified how the following reflective design features which are currently used in GBL can enhance the learning process: 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; 4) other reflective features, such as reflective modes, lead to improve critical thinking, problem-solving, and retention rate. Multiplayer role-playing games can also contribute to the improvement of the learning rate.

Despite the increasing incorporation of reflective design in GBL, there are still a few apparent limitations of practical implementation and using reflective design as a whole set instead of using it as a part. As the fast-growing trend of social collaboration is considered to be an important factor of public reflective learning, many GBL environments use social collaboration to enhance learning. However, it is hard to find a study that integrates a whole reflective social discourse within technology. For example, a few games in the reviewed articles have multiplayer in-action reflective features but offline post-gameplay assessments or debriefs. Many of these studies used offline peer collaborations, reflective assessments, and face-to-face workshops to enforce reflective learning.

Most of the studies have incorporated in-action social discourse by playing a game in a collaborative environment among participants (Foster et al., 2019; Hautopp & Ejsing-Duun, 2020; Henriksen & Lainema, 2010; Martin et al., 2011; Misfeldt & Gjedde, 2015; Rüth & Kaspar, 2021; Sinensis et al., 2019; Van Lippevelde et al., 2016; Weitze, 2017). Network-based technology enables users to participate in a multiplayer environment; Orji et al. (2013) have developed role-playing multiplayer games to enable shared learning experience, collaboration and social reflection. Apart from in-action reflection (Schon, 1983), reflective design features are highly incorporated in post-gameplay as an on-action reflection in GBL. In this review, most of the studies were comprised of offline post-activity assessments (Foster et al., 2019; Henriksen & Lainema, 2010; Hwang et al., 2015; Rahmani et al., 2013; Wu et al., 2018) with guided instructions (Rüth & Kaspar, 2021). Moreover, the post-competing reflective activity (Anderton & King, 2016; King, 2015; Orji et al., 2013), face-to-face post-play workshop on assessment (Martin et al., 2011), and self-reflection process of behaviour change identification technique are used for on-action reflection.

In addition to Schon (1983) in-action and on-action framework, researchers are now incorporating other reflective models, such as Gibb's Reflective Cycle (Gibbs & Unit, 1988) or Kolb's Learning Cycle (Kolb, 1984). Hence, it is a new research field to ensure reflective learning technique's accuracy, and there is a need to drive a mechanism to incorporate reflective learning measurement methods to identify design improvement.

2.3 GBL Frameworks

Games are one of the fastest growing sectors of the modern world, and are a commonly used entertainment source among young people (Ahmad et al., 2014; Tan et al., 2007). Various GBL frameworks have been developed over the years to best understand how games can be used to engage learners in course material. Killi's Experiential Gaming Model (Kiili, 2005) focuses on combining experiential learning theory, flow theory, and game design to create a successful GBL model. It emphasizes that the use of immediate feedback along with clear goals and challenges matched to the players' skill level allow for meaningful and engaging learning by experiencing flow. She found a lot of consistency in achieving the facilitation of flow, though, which makes the model unpredictable to follow. Furthermore, the model is suggested to be used for the design and analysis of educational games, and not for game development.

Components	Pedagogical										Game Design											
Elements / Models/ Frameworks	Difficulty to learn	Psychological needs	Critical thinking	Exploration	Challenge	Engagement	Competition	Practice	Goal setting	Motivation	Interaction	Storytelling	Interface	Simulation	Construction	Feedback	Literacy	Communication	Motor skill	Memory	Outcome evaluation	**Total**
The Design Framework for Edutainment Environment	✓	✓			✓					✓	✓	✓	✓								✓	8
Adopted Interaction Cycle for Games									✓	✓	✓					✓			✓		✓	6
The Engaging Multimedia Design Model for Children						✓			✓		✓			✓	✓	✓					✓	7
Game Object Model			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓		15

Figure 2: Matrix outlining key components of the 4 frameworks investigated in the development of AGBL (Tan et al., 2007)

The Adaptive Digital Game-Based Learning (AGBL) framework (Tan et al., 2007) identified key elements from 4 other GBL models and frameworks (see Figure 2). It has a preliminary focus on the pedagogical elements, such as psychological needs, cognitive development, and learning behaviours, in order to understand the learners' learning abilities so that the game can be tailored toward the target group. Closely followed are the game design aspects, namely multimodal, tasks, and feedback. Unlike other models, which primarily focus on interaction in their game design, AGBL highlights the importance of engaging and motivating learners in the GBL environment using story, challenges, goals and objectives, with a focus on feedback and outcomes. This model places a good emphasis on the pedagogical elements of GBL, with the inclusion of multimedia elements to further engage players. The use of feedback and outcomes could be useful in encouraging reflection through gameplay.

GBL is a vast field now, and therefore, there is a gap in the literature about its core dimensions for comprehensive evaluation due to varying use of elements. In an effort to overcome the inconsistency in-game elements, scope, terminology, and definitions, Tahir and Wang (2018) expanded on GBL evaluation literature by conducting directed content analysis. Specifically, they analysed results to construct a hierarchal framework known as LEAGUE, which uses six core dimensions: Learning, Environment, Affective-Cognitive Reactions, Game Factors, Usability, and User. This framework provides a detailed overview of GBL elements and can act as a theoretical guide for designers, researchers and educational game developers.

In terms of cognitive engagement, Silpasuwanchai et al. (2016) proposed the Engagement Framework of Gamification for Learning in a study that investigated the use of gamification strategies to increase engagement, skill acquisition and transfer. This framework focuses on multi-faceted engagement (behavioural, emotional, and cognitive), users (internal states and characteristics) and tasks. Their research yielded that the use of multiple engagement dimensions is useful in different situations depending on the situation. In the post-study interview, they established that cognitive engagement was often high and even with a low emotional engagement, the effort (behavioural) and reflection (cognitive) which were put into achieving a good result stayed high.

Although games are inherently reflective by nature, very few of the previously mentioned GBL frameworks use active reflection methods or reflective practices to engage the player in learning. According to the literature review, only Kiili (2005) mentioned reflective feedback in her Experiential Gaming Model, even though her primary focus was on using the flow theory to develop a GBL. The development tool ctrl+R is designed to "prompt new – and reflective – ideas among game makers" through the "previously unconsidered creative avenues" (Goodine & Khaled, 2019) by presenting designers with eight random questions on digital "cards". This tool could be useful in conjunction with one of the GBL models to enhance reflective game design.

3. Reflective Game Design (RGD) Framework

In literature, there are several reflective models (Argyris & Schön, 1978; Gibbs & Unit, 1988; Kolb, 1984) to guide reflective design in learning. Although each model is designed to induce reflective learning in a specific way,

Kolb's Learning Model (Kolb, 1984), famously known as the "experiential model", aligns with the GBL purpose as it is based on experiential design and enables concrete experiences. Kolb's Learning Model, represents a process whereby knowledge is shaped through actual practice and experience transformation. This experiential cycle comprises four distinct stages, i.e., concrete learning, reflective observation, abstract conceptualization, and active experimentation. This continuous cycle assists effective learning throughout the learning process.

1. *Concrete experience* refers to gaining an experience by actual practice; it might be a new learning experience or a revaluation/interpretation of existing knowledge in the light of new concepts.
2. After the concrete experience, *reflective observation* allows learners to revisit and reflect on reassessing their experience, such as learners should step back to reflect on the task or activity. Moreover, at this stage, critical reflection can be achieved by asking questions, discussing with peers and comparing new knowledge with previous experiences to look for patterns or notable differences.
3. Reflective observation leads to *abstract conceptualisation*; in this stage, learners form new concepts or modify their current understanding based on reflective observation. Abstract conceptualisation enables learners that are ready to apply their new learning or set of experiences in the real world.
4. The last stage of the cycle involves *active experimentation,* where learners actively apply their new skills to the world around them. At this stage, new learning is part of the learners' skill set and they are ready to enhance or improve their experience by experimenting with different ideas and opportunities. Active experimentation also leads to new ideas and innovations that can eventually become part of new concrete experiences that effectively trigger the beginning of the next cycle.

Authentic practice and reflective observation are the main components of the experiential learning model, and games are an excellent medium for providing authentic practice (Kapp, 2013) and reflective observation (Sengers et al., 2005). Thus, the primary purpose of the proposed RGD framework is to map game design elements with experiential learning and present a method to design GBL experiences that can improve reflective and authentic practice through games. Similarly to Kolb's model, the RGD framework consists of four stages, where each stage is extracted from the original experiential learning model. Figure 3 depicts the assignment of game design elements to each stage of the Experiential Learning Cycle.

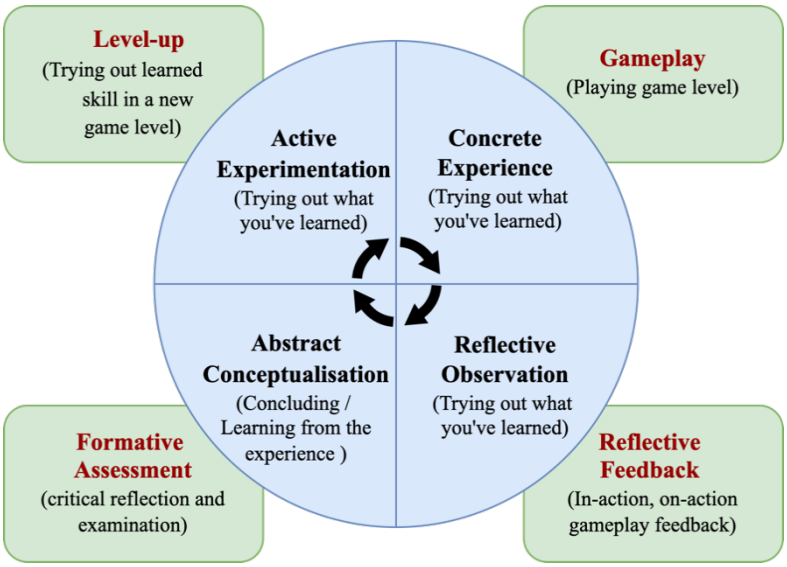


Figure 3: Experiential Learning Cycle (inner circle Kolb, 1984), and assignment of game design elements to each stage of the Experiential Learning Cycle

1. *Gameplay in GBL* enables learners to interact with a game to get an authentic practice and concrete experience of a learning objective. It is the pattern defined through the game rules, game mechanics, challenge, story, feedback, levels, and other game elements. Moreover, gameplay in GBL allows the freedom to replay and explore the content to improve learning skills. For instance, CodinGame (https://www.codingame.com/) is an online game-based learning solution that helps programmers to

improve their coding skills by solving challenging problems (Figure 4(a)). In this platform, each gameplay is built to learn and practice new concepts of different programming languages, e.g., the "if-else condition" concept in Python.



Figure 4: Examples of a) Gameplay, b) Reflective feedback

1. *Reflective feedback* is an integral part of the RGD framework. Games provide two types of reflections: 1) In-action reflection refers to reflective feedback during gameplay in Heads-up displays (HUDs), reflective prompts, process models, audio/visual feedback, and social discourse. For instance, in CodeCombat (https://codecombat.com/), the reflective feedback is used to highlight the player's code, line by line and visualise the result of a player's code in a playback (Figure 4 (b)), and visualise students' actions to help learners reflect and examine their process to improve learning skills (Lin et al., 1999; Villareale et al., 2020). 2) On-action reflection refers to post-gameplay reflection, such as leader boards, progress information, comparative charts with previous progress, and star rating. For instance, CodinGame used a community voted leader board, allowing players to view higher voted solutions.
2. *Formative assessment* ensures the players' learning and critical reflection by ongoing reflective feedback and examining their skills in gameplay. Games can provide an interactive and fun learning environment to conduct an assessment, and game mechanics are helpful tools to assess learning implicitly. These assessments can be conducted in-gameplay or post-gameplay. For example, CodingGame uses "Play Test Cases" to test learning step-by-step.
3. *Level-up* is active experimentation of a learned skill in a new environment or situation. Level designing is also an essential element of game design, and each level-up with embedment of using previously learned skills can improve authentic practice and learning. For example, CodinGame's "Power of Thor, episode 1" introduces players to "if-else" conditions by a simple puzzle and follows it up with "Power of Thor, episode 2", where players must solve a more advanced puzzle based on "if-else conditions" to learn a new concept.

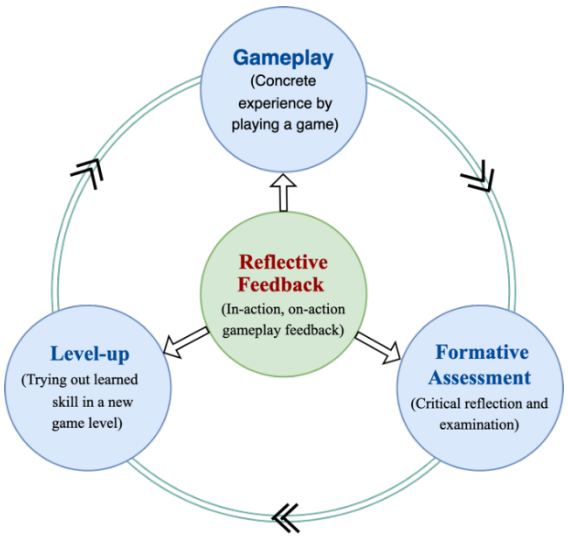


Figure 5: RGD designed Framework

The RGD framework is an iterative model, in which each iteration improves learning with reflective observation and authentic feedback. Reflective feedback is a central part of this framework as shown in Figure 5, thus, this framework embeds reflective learning elements in each stage with experiential learning (Kolb, 1984) methods

4. Conclusion and future work:

This paper primarily focused on presenting a reflective game design framework (RGD framework) that enables the use of the reflective nature of game elements in game-based learning. The RGD framework provides a mechanism to incorporate reflective learning in GBL approaches that will provide learners with reflective feedback at each stage of the RGD framework. Previous studies suggest that reflective design features in GBL improve the learning process, e.g., Heads-up displays improve understanding, social discourse enhances user experience with active engagement, and other reflective features, such as reflective models lead to improved critical thinking and problem-solving. Despite the importance of the reflective nature of game elements, previous studies have not addressed it entirely. Therefore, this study intends to add more knowledge and evidence in this field by proposing a reflective game design framework for GBL design and development. This framework is modelled after Kolb's learning cycle and maps game design activities with experiential learning theory.

In the future, this RGD framework will be implemented in the design of a serious game to improve self-awareness among youngsters, and its effectiveness will be evaluated accordingly. Moreover, the evaluation findings will be used to inform reflective game design principles and guidelines. Hopefully, this ongoing research will provide some insight and help GBL designers and researchers to implement reflective design in their practice.

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Adaptability and Procedural Content Generation for Educational Escape Rooms

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Abstract: We present a literature review that aims to understand the role of the Educational Escape Room (EER) in improving the teaching, learning, and assessment processes through an EER design framework. The main subject is to identify the recent interventions in this field in the last five years. Our study focuses on understanding how it is possible to create an EER available to all students, namely visually challenged users. As a result of the implementation of new learning strategies that promote autonomous learning, a concern arose in adapting educational activities to each student's individual needs. To study the adaptability of each EER, we found the EER design framework essential to increase the student experience by promoting the consolidation of knowledge through narrative and level design. The results of our study show evidence of progress in students' performance while playing an EER, revealing that students' learning can be effective. Research on Procedural Content Generation (PCG) highlighted how important it is to implement adaptability in future studies of EERs. However, we found some limitations regarding the process of evaluating learning through the EERs, showing how important it is to study and implement learning analytics in future studies in this field.

Keywords: Learning; Educational Escape Room; Narrative; Level Design; Adaptability; Procedural Content Generation

1. Introduction

The use of educational games as learning tools allows teaching and reinforcement learning, developing non-cognitive skills like troubleshooting, teamwork, and communication (Mateos-Aparicio et al., 2020). This study defines the EERs activities as an effective and innovative learning experience in a high-pressure situation, besides having a positive impact on student engagement and learning (Dugnol-Menéndez et al., 2021).

The game's narrative is a crucial component of that initial impact, which motivates the player to play (Manzano-León et al., 2021). So, to engage all stakeholders, it is essential to adapt the narrative through good storytelling in which the World Design is well defined and developed. The EER design framework (Krekhov et al., 2021) should consider the MDA framework to outline the EER dynamic behaviour (Hunicke et al., 2004, Krekhov et al., 2021) and the Level Design to create lifelike and interactive experiences. Nonetheless, the EER framework must define the adaptability and the Procedural Content Generation objects and environments.

This paper is organised into four sections. Section 2 presents "from Escape Rooms to Educational Escape Rooms," and it is subdivided into two subsections: the first is about "Escape Rooms," and the second is about "Educational Escape Rooms." Section 3 summarises the "implementation of the new learning strategies through the EERs design." It has four subsections: the first considers the importance of the "Design framework," the second is about the "Narrative," the third is about "Level Design," the fourth is about "Adaptability concerns," and the fifth describes the "Procedural Content Generation." Section 4 presents a "Discussion" in which we summarise our findings, limitations, and the importance of this study. Section 5 closes this paper by presenting conclusions and perspectives on future work.

2. From Escape Rooms to Educational Escape Rooms

2.1 Escape Rooms

Escape Rooms (ERs) have been defined as Live-Action Games in which players must find objects with clues that address solving puzzles and finish the challenge(s). ERs take place in one or more rooms to improve and reach a specific goal (Veldkamp et al., 2020, Bakkum et al., 2021, Morrell and Ball, 2020, Karageorgiou et al., 2020, Jambhekar et al., 2020, Karageorgiou et al., 2019, Archontoula and Skoumpourdi, 2019).

The first real escape games appeared in Japan in 2007 and spread rapidly throughout Europe (Borrego et al., 2017, Moreno-Fernández et al., 2020, Krekhov et al., 2021). Recently, ERs have become a popular leisure activity because it offers a wonderful opportunity to spend time having fun, as well as to conduct a “teambuilding” activity by joining members of an organisation to troubleshoot, through the encouragement and the development of team spirit (Moreno-Fernández et al., 2020). So, there are many different or similar forms to refer to ERs: “escape game” (Borrego et al., 2017, Dietrich, 2018), “room escape” (Borrego et al., 2017, Sanchez et al., 2017), “breakout” (Leon et al., 2020, Nephew and Sunasee, 2021, Perumal-Pillay and Walters, 2021, Pozdniakov et al., 2021, Zouhri and Lee Running, 2021); “exit game” (Murto and Välimäki, 2011) or “unlock” game (Eukel et al., 2020).

According to Krekhov et al. (2021)., ER can be played by one or more players depending on each form or platform. Some rooms may include a game master and actors to add realism. Moreover, it can also be played in various ways depending on the place and device. The analogue ERs are presented in many forms and often use cards to display rooms, items, and text or combine various materials. Hybrid games combine analogue and digital elements by adding a digital camera or companion app, which usually provides hints, surprises, and multimedia content. Digital ERs often present rooms and puzzles in 2D or 3D graphics and use simple point-and-click or touch mechanics. However, others are predominantly text-based and work with text commands.

Virtual Reality Escape Rooms (VRER) provide human-computer interactions easier and the collaboration between the elements of the team more efficient – generating high immersion, like the student feel living their real-life (Li and Han, 2021).

2.2 Educational Escape Room

The use of educational games as learning tools allows teaching and reinforcement learning. Moreover, it develops non-cognitive skills like problem-solving, teamwork, and communication (Huang et al., 2020), beyond curiosity for students to discover scientific concepts, motivation and engagement comparable to the traditional educational games (Borrego et al., 2017, Nicholson, 2018, Gómez-Urquiza et al., 2019, Huang et al., 2020, Moreno-Fernández et al., 2020, Bilbao-Quintana et al., 2021, Dugnol-Menéndez et al., 2021, Macías-Guillén et al., 2021). Students may develop their learning path playfully and their own adaptive and responsive skills. As an alternative to traditional activities, students participate in a fictional story and attempt to achieve a fictional objective within a specific time by solving puzzles and challenges related to curriculum content within a limited duration with the help of their peers (Manzano-León et al., 2021). EERs are being used to improve and innovate teaching practices and positive feedback from students. According to Gaia Bistulfi (2021), the EERs develop team skills in Science, Technology, Engineering, and Mathematics (STEM). Still, we also found it in other fields, particularly in health sciences (Macías-Guillén et al., 2021). Jimenez et al. (2020) also pointed out that using EERs offers many advantages to students, including intellectual, social, emotional, and psychological benefits. For that reason, EERs have been used for various educational goals like (1) recruiting students; (2) for students to get to know institutions; (3) increasing students’ cooperation; (4) in a research environment; (5) observing students’ information search behaviour; (6) learning processes in student teams; (7) teamwork and leadership skills; (8) fostering design skills, domain-specific skills, and knowledge; (9) or even, to support the development of generic skills.

Most authors tend to describe the EER activity as "gamification" (Sanchez et al., 2017, Li et al., 2019, Pérez et al., 2019, Leon et al., 2020, Lopez-Belmonte et al., 2020, Bistulfi, 2021, Dugnol-Menéndez et al., 2021, Santos and Moura, 2021) although others as a "serious game" (Mystakidis et al., 2019, Brown et al., 2019). In both cases, students are meant to be motivated and engaged by the activity, and there has been extensive research on their differences (Mayer, 2016, Macías-Guillén et al., 2021). However, EER is also described as a playful learning activity. EER uses play and playfulness to facilitate learning through the "magic circle of playful learning" – students take managed risks safely and learn from failure – and the "lusory attitude" or "spirit of play" –

students face difficult or unfeasible situations in the "real world" (Whitton, 2018). EERs can also be used for problem-based learning (PBL) since their features are also included in the ER scenario with an “ill-structured” or “messy” problem within a “real-life scenario” and respective concepts. Students are encouraged to solve challenges they can find through open-ended tasks, endorsing their autonomy and collaboration with their peers (Pearcy et al., 2019, Krekhov et al., 2021).

According to Dietrich (2018), it is an opportunity for students to compete with and against their classmates, show off their skills, interact, and discover new things. So, the level design features are essential for EERs to engage students through VR design tools (Caldas and Keshavarzi, 2019), fitting the concept of game-learner-centred and problem-solving-oriented learning (Huang et al., 2020). EER designers are advised to use a thoughtful, methodical, iterative process to ensure quality, educational capacity, and a positive learning experience. To improve the educational simulations, they should be based on student needs, context-based, student-centered, and constructed based on measurable purposes (Eukel and Morrell, 2021).

3. Implementation of new learning strategies through the EERs design

3.1 EER Design Framework

The EER design framework presents important design considerations to the creation process. Krekhov et al. (2021) pointed out that developers should consider in the first place the target audience and setting's theme. Second, developers should provide mini-games defined by challenges, starting from prior works and known classifications, leading to the basic version of anatomic mini-games taxonomy. So, from this point, it’s suggested to refine, improve, and validate the EER. It is also highly recommended to start from the analogue and then proceed with the digital versions. It is meant to have an overview of the state of the art, analysis, and classification of analogue and digital EERs. This framework can be applied to simplify and streamline the design and decision-making process for the researchers and practitioners involved in it.

ERs have different game mechanics and input modes but share a similar conceptual structure with a series of connected puzzles at their core. By consolidating the evidence from related work, Krekhov et al. (2021) identified the main design aspects of ERs: target group/team and composition; theme/narrative; modalities/platform; puzzle organisation and design; and clue system and resilience. On the one hand, the first three features provide the framing for creating the room concept and puzzles. On the other hand, the last three describe more specific aspects of the puzzle design and composition. Clarke et al. (2017) presented a study of a theoretical design framework for EERs (“escapED”), which defines six steps of the process (Figure 1).

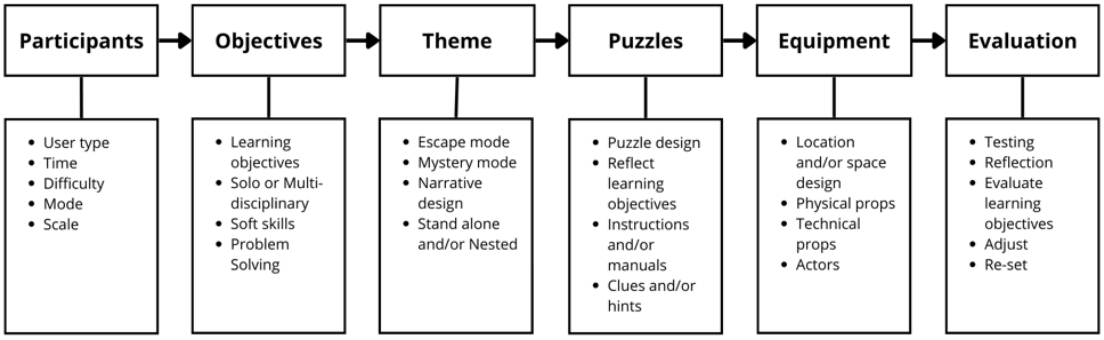


Figure 1: escapED Framework (Clarke et al., 2017)

Synder Escape Room FrameWork (SERF) extends the escapED framework (2020) because Synder (2018) suggested that other design concepts and heuristics should be added due to the fact that each phase has an impact on the others, and this should be considered when designing an EER (Figure 2).

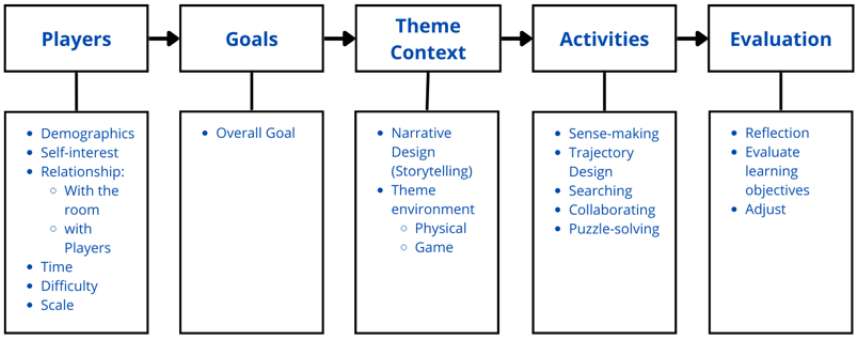


Figure 2: SERF Framework (Snyder, 2018)

So, Seebauer et al. (2020) developed the EduER framework combining all the escapeEd (black) basic procedures with all the essential factors of the SERF framework (blue). This combination resulted in six phases (Figure 3). The study design and usability conducted with the EduER framework presented that it is obvious to determine findings without questionnaires, e.g., timeframe, because some participants didn't realise when the task was finished and could continue to do the next one.

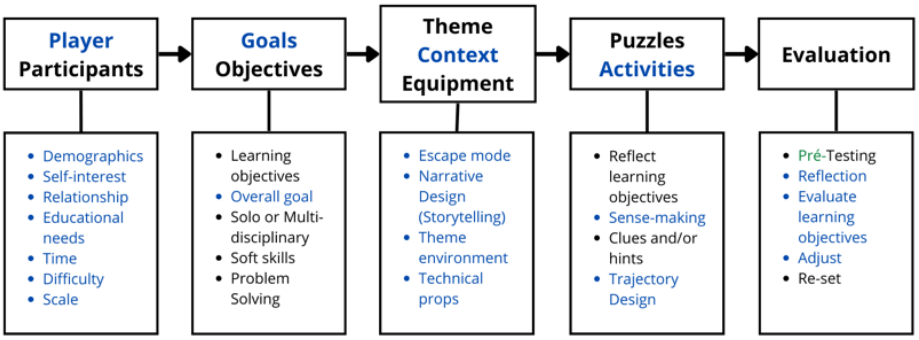


Figure 3: EduER Framework (Seebauer et al., 2020).

Moreover, Jimenez et al. (2020) considered EER design to outline: the specific context to place the action, revealing the general information like the game rules to the participants, considering the game director or game master, participants, puzzles, and the sequence of the game (linear path, open path or multilinear).

3.2 Narrative

According to Itenge et al. (2021), narrative development is part of a co-design project whose goal is to co-create a game that causes emotions that result in an immersive experience for the participants. ERRs learning environment commonly involves a mystery (Veldkamp et al., 2020), with adventure, real-world team-based, and problem-solving (Avargil et al., 2021). So, to potentiate the feeling of fun, it is essential to use some game methodologies throughout the game narrative. It is possible to choose two different kinds of narratives. First, the emergent in which the player is free to do what she/he pretends, and the quality depends on the choices made by the player; or the second, in which a story is well defined and the player doesn't have any option to change the game path (Champagnat et al., 2009). As Zagal et al. (2005) and Champagnat et al. (2009) pointed out, a game framework should describe the game elements based on the interface, rules, objectives, and entities.

3.3 Level Design

It is fundamental to consider the relationship between rewards and difficulty when designing a game. According to Li et al. (2021), game designers must know how to match the level design (LD) to this relationship fundamental in their game's mechanics. LD pretends to find the equilibrium with the game elements and sequencing them to promote engagement and satisfaction, besides forming a coherent experience in which the player can be defeated or pass a game element. Dormans (2011) pointed out that using rewrite systems to formalise LD principles enables level designers to increase their efficiency in designing levels and reduce the possibility of mistakes. Level designers can use model transformations as part of an adaptive framework where missions are generated before space or vice versa. Generally, action-adventure games benefit from utilising mission and space grammar to generate various quality levels (Dormans, 2010). So, developing spaces for missions allow multiple paths to converge on the same goal. A framework that will enable a level designer the possibility of

generating game mechanics during the level generation process allows simultaneously the chance to create game levels that better integrate the unique elements that define the gameplay of a game.

3.4 Adaptability concerns

The user-centred design focuses on using the system, applying some characteristics defined by the International Organization for Standardization. These characteristics include an iterative design process, users' participation in the design, evaluation of the user experience, multidisciplinary perspectives and skills, and understanding of end-users, tasks, and environments (Doroudian et al., 2018).

In the EER design process, it is crucial to know the target group – the audience (Clarke et al., 2017) – to create an experience personalised to their needs. This kind of setting's adaptability could include an appealing theme, an appropriate difficulty level, and a mix of challenges that fit their skills. Mainly, if a design is meant for people with special needs, a need assessment is crucial, and it is recommended that the target group be involved in the design process (Menzies, 2019).

The common adaptability flaw in game development is to design immersive games without triggering lights or colours. Epileptic seizures related to video games started to be noticed in January 1993 with the *Super Mario World* game. In this sense, understanding how some games are more provocative with visual stimuli than others is essential to preventing and designing a safe EER. Two tools to help developers to choose EERs' colours are ColorADD (2022) and Adobe Color (2022). So, the proximity settings, patterns, background colours, and contrasts proved crucial to understanding how each parameter affects these users (Kasteleijn-Nolst Trenité et al., 2002).

3.5 Procedural Content Generation

Procedural Content Generation (PCG) refers to creating game content (semi-)automatically through algorithms, providing the possibility to generate personalised games that the player can adapt according to his preferences and optimise the gaming experience. So, these features allow a wide range of content production and elements such as terrain, maps, layers, stories, dialogues, quests, character rules, dynamics, or weapons (Korn and Lee, 2017).

There is a constant challenge for PCG algorithms to implement the quality/diversity paradigm to find the set of diverse and high-quality solutions in a single run (Gravina, 2019). The EER designer must consider the rules and environment of the game. According to Murray (2017), PCG designers, besides settling the narrative possibilities, in the education field, should provide a layout that gives the player the freedom to explore and improvise, indulging in a spontaneous strategy to reach what students believe that it is some sort of reward. In our study, we found that Houdini (SideFX, 2022) and Unity (Unity, 2022) allow to develop ERs more immersive. So, EER developers should consider these tools to build games with graphics more realistic.

4. Discussion

EER designers should consider some specifications in the EER design framework, narrative, LD, adaptability, and PCG. However, they also should have concerns depending on students' differences, like regional or cultural, in how they prefer certain theme types or challenges, as Krekhov et al. (2021) pointed out.

In future studies, researchers may find some issues in implementing PCG in an EER with adaptability concerns, depending on the students' needs. However, EER should use the PCG methods for specific parts that can be organised based on a taxonomy of six layers (bits, space, systems, scenarios, design, and derived content) ordered by the complexity. Each layer uses techniques and methods from the layer before (Hendrikx et al., 2013). However, the progress of EERs built on PCG depends on a multidisciplinary team from the field outside computational intelligence (Togelius et al., 2011).

We found some gaps related to the use EERs by visually challenged people, such as photosensitivity, colour blindness, and epilepsy. During this study, we also perceive the EERs assessment processes aren't being deeply studied. A deeper understanding of these topics can be gained by conducting further research.

5. Conclusions

Students are accustomed to technology and expect the school to provide innovative learning materials and methods. By promoting autonomous learning, new learning strategies enable the development of learners'

autonomy, especially for learners with disabilities. To study the adaptability concerns, we found that the EER design framework is essential to increase the student experience by promoting the consolidation of knowledge through great narrative and a high-level design. There is not yet a specific EER framework that has to be followed step by step by all developers, which gives more freedom of creation and design to adapt the EER to the educational needs and, if needed, special needs of its stakeholders. We verified that students have more significant gains when playing an EER than using traditional learning methods. Adaptability is becoming more evident in game development, potentiating the flow and immersion in the game, allowing an improvement in participants' experience. To develop an EER for the scholar community, with inclusion and adaptability concerns, designers should consider the different participants' needs because health issues shouldn't compromise their education. PCG increases the students' motivation, so it should be considered in future EER applications. Overall, the results of our study present evidence of progress in students' performance while playing an adaptable EER than traditional learning approaches.

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Dark Pattern: A Serious Game for Learning About the Dangers of Sharing Data

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Abstract. Dark patterns refer to tricks built into websites and apps to manipulate users into acting unintentionally and detrimentally. An important issue is how such patterns might affect behaviour when actors are manoeuvred towards the sharing of their personal data, as exemplified in choices we face when downloading Apps or signing up for services provided on the internet. This paper presents our exploratory research into understanding the intention and subsequent actions of older teenagers responding to issues of personal data collection and (mis)use. The research is based on the competitive board-game *Dark Pattern*, in which players install apps, draw dark pattern cards, and make choices about the sharing of personal data. To win the game, a player must share as little data as possible and play cards that punish other players. We were interested to find out the extent to which the game was able to convey types of dark patterns to the players. Additionally, we wanted to explore how players' perceptions of risks in data-sharing associated with their intention to protect their personal data. Finally, we were interested to explore potential gender difference, and whether this might be associated with intention to protect personal data. 56 of the students who played the game answered a subsequent survey with questions about their experiences and the data was analysed using Partial Least Squares – Structural Equation modelling (PLS-SEM). Despite the findings showing that playing the game had only limited impact on knowledge about dark patterns matters, the analysis of the relationship with the factors in our model shows that knowledge has a significant contribution on behavioural intention, demonstrating that students with high dark pattern knowledge also report higher intention to take steps to protect their data.

Keywords: dark patterns, Serious games, learning, user-test, exploratory study, sharing of personal data, personal data security, partial least squares path modelling

1. Introduction

As everyday life becomes increasingly digitized, website and app developers have been collecting considerable amounts of data from internet users. In response to society's concern regarding what seems to be the discreet practice of excessive data collection, general regulations have forced online platforms to implement a notice-and-consent regime. That is, platforms must give users the option to consent or not to the data collection via an active accession, in this case by confirming through a 'click'. The notice-and-consent regime, however, is based on the myth that human decisions are entirely free and rational (Acquisti, 2015) when, in reality, decisions are more greatly constrained by contextual factors. Several online services benefit from this interpretive flaw by implementing so-called Dark Patterns, also known as deceptive design patterns. Dark pattern was a term coined by UX expert Harry Brignull (Brignull et al., 2015) to refer to interface design strategies used by websites and app developers to manipulate or trick internet users into agreeing to disclose their personal information. One of the problems with dark patterns is that, in general, this type of tactic serves the benefit of the online service, rather than the user.

The darkpattern.org website lists what are considered to be the most common techniques of manipulation. Some examples of these tricks, which are covered in our research, are known as *Roach Motel*, *Privacy Zuckering*, *Disguised Ads* and *Friend Spam*. *Roach Motel* is a graphical interface that makes it easy to subscribe, register, or sign-up for a service but more difficult to cancel this operation at a later juncture. *Privacy Zuckering* refers to Facebook's (and its CEO, Mark Zuckerberg) early strategies of presenting obscure "Terms and Conditions" and

"Privacy Policies" that tricks users into publicly sharing more of their personal information. *Disguised Ads* are advertisements disguised as other types of navigation content. *Friend Spam* consists of requesting email or social media permissions to present a desirable outcome for the user (e.g., connecting with friends) but then spamming the user's contacts.

Internet users frequently cite a lack of understanding to justify their privacy choices (Brandimarte, 2013, Williams et al., 2017). Some researchers argue that awareness about privacy choices and their negative consequences is the first—although not only—necessary step to mitigate data disclosure (Deuker, 2010; Pötzsch, 2009). Disclosing or releasing personal information is the conscious action of willingly sharing some information that is private or individually identifiable with a certain individual or group. Therefore, it is important to educate citizens about the existence of dark patterns aiming to circumvent their awareness, while informing them of the increasing importance of protecting their data privacy. Serious games are one way to achieve this and have been considered an effective strategy to train and educate users on varied topics (Alamri et al., 2013). More specifically, as Jost and Divitini argue (2021:16): *Competitive games with a scoring mechanism have advantages from an educator viewpoint as they are easily explained in teaching scenarios and quantifiable for comparative evaluation of learning progress*. This was the motivation for the development of a serious, competitive game aimed at informing individuals about such deceptive mechanisms used by many organizations. In order to understand this in more depth, we invited participants to play a game and measured their degrees of understanding of the dark patterns and risks. Subsequently, we evaluated if these variables were predictive of higher intention of engaging in privacy protection.

2. Method

2.1 Participants

The participants in this research were 56 high school students aged ranging from 16 to 18 years old; 32 female and 24 male students. These 56 are the students who played both the game and used at least 4 minutes on the questionnaire without providing the same response (for instance 3) for most of the questions. In a survey, if a respondent clicks on the same number, for example, 6 (=extremely likely) for all or almost all of the questions, the respondents will be deleted from the dataset being regarded as untrustworthy responses. This answering pattern indicates that the respondent either did not read the question or that no thought was given to their response.

2.2 Procedure

Participants were recruited in three upper secondary schools: one school in Copenhagen, Denmark, and two schools in Oslo, Norway. The research was conducted in the school classroom within a 50-min class. The participants were required to play The *Dark Patterns Game*, then answer a questionnaire.

First, each class teacher divided participating students into groups of 4 or 5, some groups including both genders and some with one gender only. Next, the students watched a short introduction and a 90-second video published on Vimeo about the game. Then, the students took part in a rehearsal session that lasted approximately 15 minutes. The game itself has a duration of 20-30 minutes per round. While playing the game, the students read or skimmed through the printed manual of game rules. For those requiring further information, the teacher and one representative from the developers answered questions about the rules and how to play. Finally, after the rehearsal, the students started to play the game. After finishing the game, the students calculated the score for each player, and based on the game score, the winner of the game was declared. When the students had finished playing, they were asked to fill out a questionnaire, which they could access on their own mobile phones.

2.3 The Game

The *Dark Pattern Game* was developed in collaboration by the company *Serious Games Interactive* and the Norwegian Computing Center, a non-profit private foundation. It was inspired by the master thesis, Serious Interactive Board Games: Increasing Awareness of Dark Patterns in Teenagers written by K. M. Nyvoll (Nyvoll, 2020). To the best of our knowledge, we are not aware of other dark pattern games aimed specifically at this age group and for this purpose. The game design was intended to be endogenous in form, where there is a close overlap between game mechanics and learning objectives to increase retention and transfer (Egenfeldt-Nielsen, 2019).

The *Dark Patterns Game* is a board game to be played in groups of three, four, or five people. Although the game is about apps, it is presented in a physical rather than digital format (that is, as a printed board game). The game contains a mobile-shaped board with nine app slots, five player-boards, dark pattern cards, fictitious apps, and cubes representing data types. The cards describe the name of the dark patterns, their mechanisms, and their consequences for users. Examples of cards and apps are presented in figures 2 and 3.

The first information players receive in the manual is*: "You just got a brand-new phone. You all want your type of apps on the phone (dating, SoMe, games, health, shopping) without giving away too much data about yourself*." Therefore, first, each player must choose a Player Board that defines one of the following roles: the Shopper, the Gamer, the Influencer, the Lover, and the Healthy. When playing, apps must be chosen according to the role. For example, the Shopper must install shopper apps on the mobile board, the Gamer must install gaming apps on the mobile board, and so on. Examples of cards and apps are presented in figures 2 and 3, presented in the next section.

The goal of the game is to have installed most of your assigned apps on the phone board without giving away too much personal data. Every time the player installs an app they must give away one or more data types. Besides, they must draw a Dark Pattern card that forces them to give away further data that they did not mean to. Consequently, the game requires players to deal with the decision of which apps to install, while being informed about the risks posed by the Dark Patterns, but in a playful manner. The player earns points by installing apps and loses points by granting data access permissions (the greater the number and type of data accessed by the apps, the greater the loss of points).

Figure 1 shows a *Plapp store* with 9 apps, with each player starting with two Dark Pattern cards as well as cubes with different colours signifying types of data. To start the game, 9 apps are placed face-up on each *App slot* on the *Plapp Store*, as shown in Figure 1. The other apps are placed face-down on the *App Pile slot*. Nine Dark Pattern cards are placed on the phone board. All apps have names. Examples of names are *Boomerbook, MeTube,* and *Poke Gogo* – see Figure 2. The names may be associated with apps available in the real world, but no actual names of apps are used.

The game progresses by a player taking and reading aloud the Dark Pattern card (Fig 3.) drawn from the phone slot - and then performing the required action, including placing cubes next to the app in question. The data cubes represent data-sharing; red is contact data, blue is media data, green is camera data and purple is location data. To win the game a player must install several apps while attempting to discard or avoid collecting as many data cubes as possible.

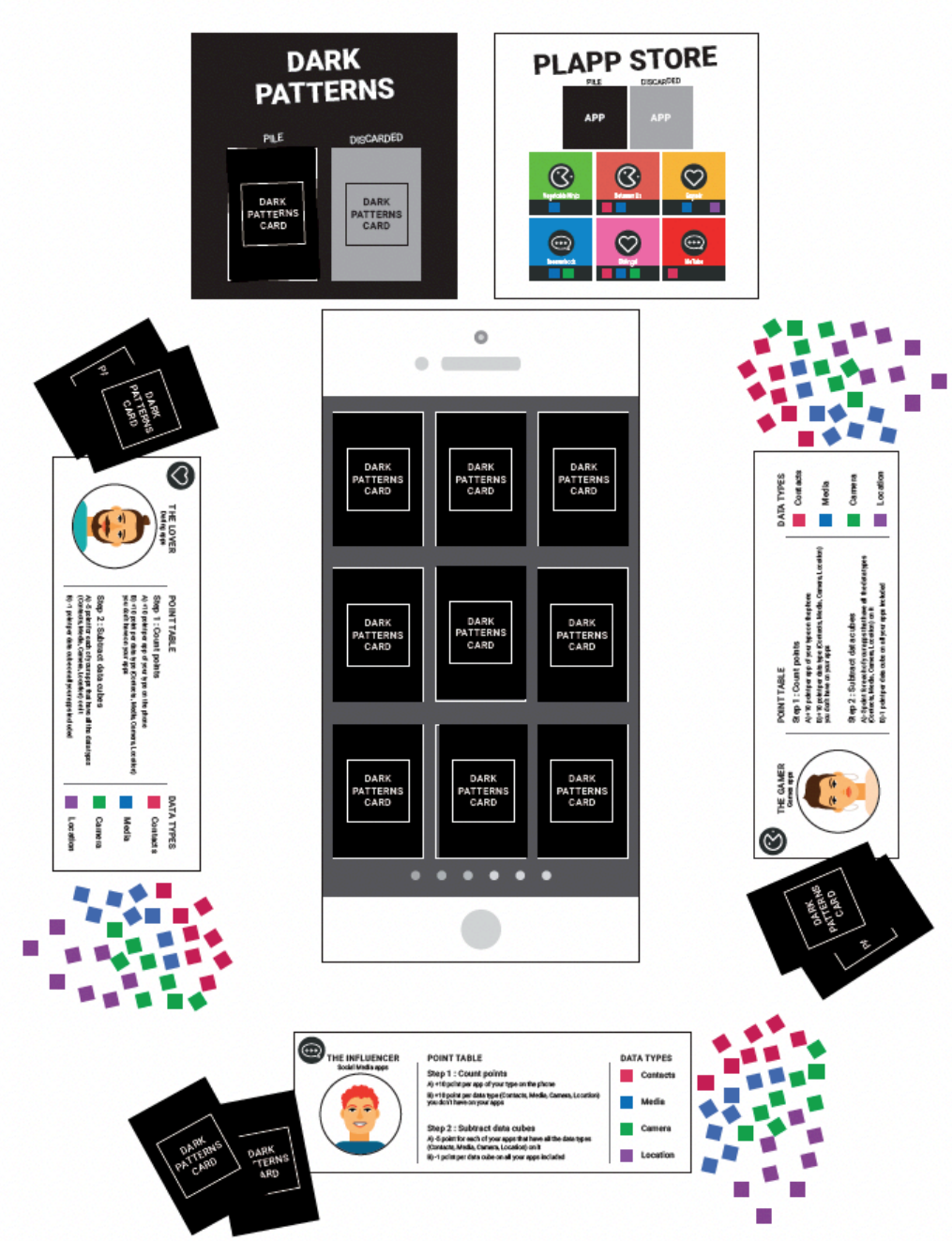


Figure 1: The set-up for the game-board with 3 players

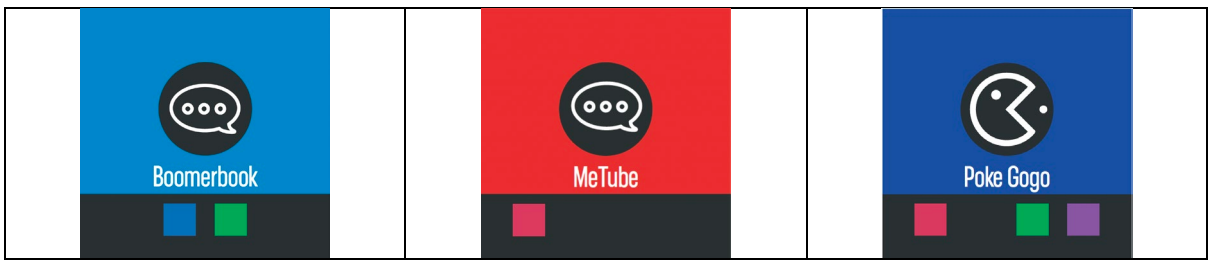


Figure 2: The apps Boomerbook, MeTube and Poke Gogo

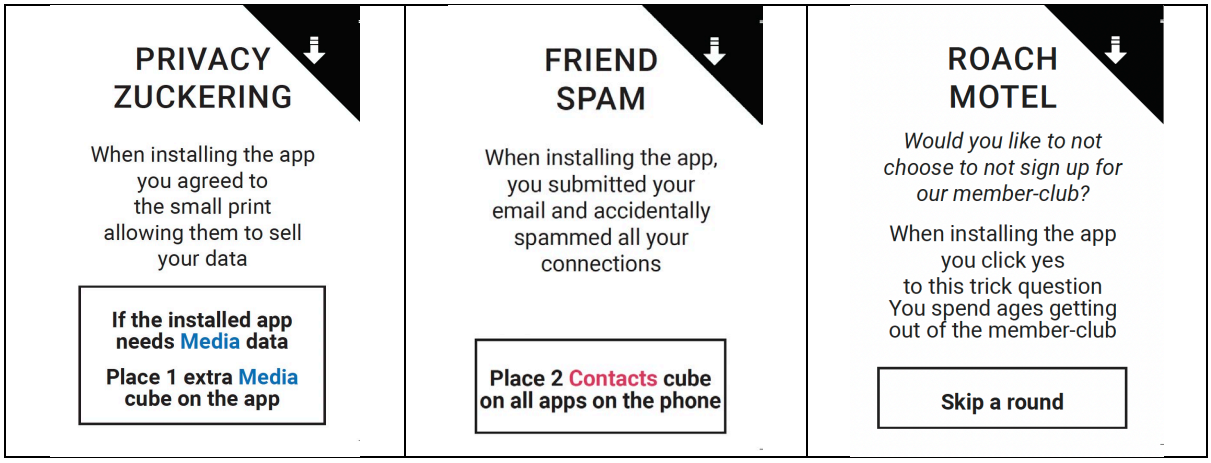


Figure 3: The Dark Pattern cards: Privacy Zuckering, Friend's Spam and Roach Motel

The rulebook for the game is the players' manual. This is available during gameplay and contains illustrations and information about how to calculate the score at the end of the game.

By reading the Dark Patterns cards and making choices about apps and cubes, the players learn about what can happen in the digital economy, along with the consequences of data-sharing. In Norway and Denmark, learning about the digital economy and developing digital judgment skills is part of the curriculum for students at upper secondary schools.

2.4 Questionnaire Measures

A battery of items measured the degree of self-reported knowledge about dark patterns, e-privacy risk perception in relation to dark patterns, and intention of performing privacy-protective behaviours. Risk perception was measured in two dimensions (probability and harm). Table 2 and 3 contain the questions (formulations) for each of the dark pattern types presented in the analysis in the results section.

2.5 Research question

There is not a finite list of dark pattern types. Some of the most common are listed by darkpattern.org. Not all, but several of the listed types are included in the Dark Pattern game.

This study was designed to understand how older teenagers respond to issues of personal data collection and (mis)use, through playing the *Dark Patterns game*, which involved them interacting with a smaller group of their peers. The questionnaire was designed to understand their experiences of playing and any knowledge gained. We have not identified scales or measurements for dark pattern types. The measurements in our work were developed by members of the research team. Consequently, we use the label "exploratory" for this research work. We formulated the following research questions targeted at students playing the game.

RQ1 To what extent did the game convey the meaning of the types of dark patterns presented in the game to the players?

RQ2 To what extent are the players of the games' risk perception of data-sharing, (the harmful consequences of data-sharing together with the probability of dark pattern incidents) associated with the intention to protect personal data?

RQ3. Is gender associated with the intention to protect personal data?

To answer these research questions, we analysed the data from 56 players with the Statistical method Partial Least Square – Structural Equation modelling (PLS-SEM).

3. Results

The questionnaire presented types of actual dark patterns. The next table presents percentages that reported that they understood the meaning or could explain the types used in the game.

Table 1: Questions about dark patterns

Dark patterns are activities to trick internet users into doing things they might not otherwise do. How much do you know about the following types of dark patterns?	Don't know what it means vs. I have a basic understanding, or I can explain the expression
Uninstall Shaming	61% - 39%
Roach Motel	86% - 14%
Disguised Ads	43% - **57%**
Friend Spam	54% - 46%
Privacy Zuckering	77% - 23%

Table 1 presents five types of dark patterns. There was only one instance where the majority of the respondents reported that they understood the type, for *Disguised Ads* 57% of respondents declaring that they understood or could explain its meaning.

For the Partial Least Square – Structural Equation modelling (PLS-SEM), as shown below, we created a variable named risk that is based on the answers to two questions. The questions with answers are presented in table 2 and 3. We used Likert scales for the answers, ranging from never (1) to always (5), from no harm (1) to extreme harm (6), and from not likely (1) to extremely likely (7). Questions with the answers 1, 2 and 3 are coded as low, 4 is coded as medium and 5, 6, and 7 are coded as high.

Table 2: How data are used by companies and perceived harm - related to 5 dark pattern types

To what extent do the following agreements/technologies feel harmful to you?	Low-medium-high
When installing an app, the install app button appeared as "download now". You clicked on the button and rather than downloading the app you were redirected to a website advertising another product. *Disguised Ads*	19% - 27% - **54%**
When installing an app, you accepted the invitation to join a one-month free member club (without knowing the conditions). *Roach Motel*	25% - 18% - **57%**
When uninstalling an app, you received a message shaming your decision. For example, "Do you really want to uninstall this game which was practically the only fun you had? Your life will be sad and gray without it!" *Uninstall Shaming*	56% - 14% - 30%
When installing an app, you gave the access to your email account on the premise that it will give you "a strong network". *Friend Spam*	31% – 23% - 46%
When installing an app, you agreed to the small print. *Privacy Zuckering*	36% – 25% - 39%

Table 2 shows that *Roach Motel* and *Disguised Ads* are perceived as the two most harmful exhibiting 57% and 54% high probability. In the PLS-SEM analysis, the risk variable is created by multiplying the score on each of these 5 with the similar 5 in table 3. For instance, 6 (=extreme harm) on *Disguised Ads* is multiplied with 6 (extremely likely) on *Disguised Ads* on how likely this incident is. Following this a scale was created; score 1 to 5 =1, 6 to 11 = 2, 12 to 17 =3, 18 to 23 =4, 24 to 29 =5, and 30 to 36 = 6. In the example with *Disguised Ads*, 36 equates to 6 on the Risk scale. In the two PLS-models we use the name PerceivedRisk_due_to_DarkPattern_activities.

In the next table, table 3, the questions about probability of experiencing the 5 types of dark pattern are presented. The scale is from *not at all* likely to *extremely likely*. The answers are summarized and presented in the right-hand column.

Table 3 Expectations - what do you think could happen? Five dark pattern types

HHow likely do you think it is that you will experience the following?	
	Low-medium-high
The install app button appears as "download now". You click on the button and, rather than downloading the app, you are redirected to a website advertising another product and starts seeing ads of that product everywhere on the internet. *Disguised Ads*	46% - 21% - 33%
You accept the invitation to join a one-month free member club and, then, you spend ages trying to cancel your membership. *Roach Motel*	50% - 18% - 32%
You give the app access to your email account on the premise that it will give you "a strong network" and the app spams all your connections asking them to join you in that app. *Friendship Spam*	46% - 18% - 36%
When uninstalling an app, you receive a message shaming your decision. For example, "Do you really want to uninstall this game which was practically the only gun you had." Your life will be sad and gray without it!" *Uninstall Shaming*	50% - 27% - 23%
When installing an app, you agree to the small print (without reading it) *Privacy Zuckering*	18% - 20% - **62%**

Table 3 shows that the respondents did not expect dark patterns often, expect for privacy zuckering with 62% high probability.

Table 4: Behavioural intentions – taking proactive steps

How often do you intend to perform the following actions in the next 30 days?	
	Never or rarely vs. sometimes or always
Putting a sticker on your camera making it impossible for apps to access your camera.	70% - 30%
Deleting and reinstalling an app to get rid of accumulated data the app had access to.	75% - 25%
Replacing apps for similar ones that require access to fewer data to function.	86% - 14%
Revising your app's permission setting so that the app is unable to access some data.	56% - **44%**

As can be seen, the majority of the respondents are not planning to take proactive steps to protect their data. Revising apps' permissions is the response option with the highest percentage, 44% - see table 4.

3.1 Partial Least Square – Structural Equation Modelling

PLS-SEM has become one of the standard tools for analysing inter-relationships between observed and latent variables in social science research (Sarstedt et al. 2019). This structural equation modelling technique can simultaneously estimate measurement components and structural components, that is, the relationships between constructs. PLS path-modeling enables the maximization of explained variance of all dependent variables and thus supports prediction-oriented goals (Henseler, 2009). With PLS-SEM it is not a prerequisite that research models are based on comprehensive theories (Barclay et al., 1995; Chin, Marcolin and Newsted, 2003), and therefore one of the reasons why it is common to use PLS-SEM in exploratory research and sometimes in the early stages of a research project.

The minimum sample size required by PLS-SEM is seven to ten times the larger number of paths leading to an endogenous construct when, as is the case in this study, all constructs except for gender are reflective (Chin et al. 2003). Convergent validity is suggested if factor loadings are 0.60 or higher (Bagozzi and Yi, 1988) and each item loads significantly on its latent construct (Gefen and Straub, 2005). Discriminant validity is suggested if all measurement items load more strongly on their respective construct than on other constructs. The square root of average variance extracted (AVE) of each construct should be higher than the inter-construct correlations – the correlations between that construct and any other constructs (Fornell and Larcker, 1981). An AVE above the recommended threshold of 0.5 indicates a satisfactory level of convergent validity. For further information about PLS as a statistical method, we refer to Chin (1998).

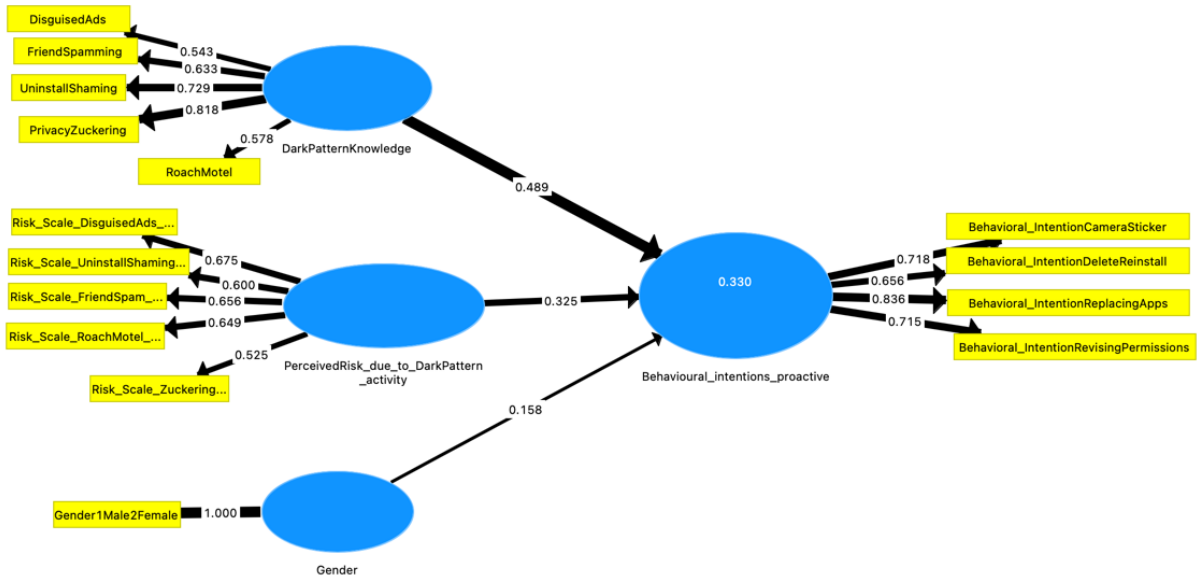


Figure 4: PLS model 1 - Dark pattern knowledge, perceived risk and gender as predictors

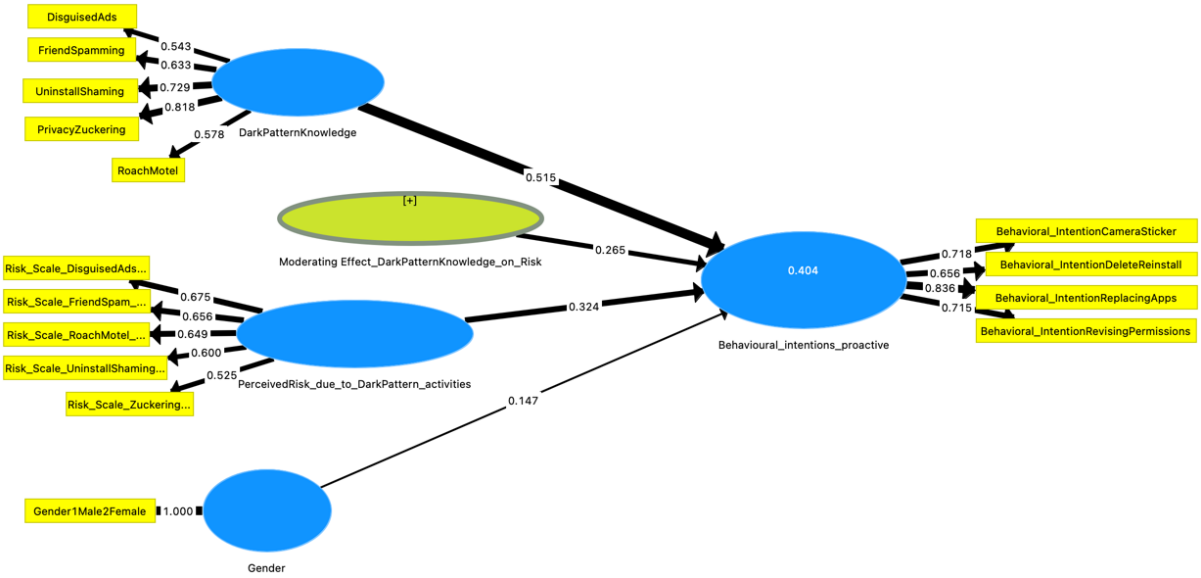


Figure 5: PLS model 2 - Dark pattern knowledge, perceived risk and gender as predictors with dark pattern knowledge as moderator.

In the figures, the thickness of the lines (also known as paths in the PLS-terminology) indicates the strengths of the association. Both dark pattern knowledge and perceived risk are significant predictors, whereas gender is not.

In the first PLS – model 1 the variance explained is 0.33 while in the PLS-model 2 it has increased to 0.4. According to Chin (1998) both register a moderate level. There is no simple answer to what is (or interpreted as) a high, moderate, and low variance explained, but a moderate level can be seen as having reasonably good explanatory power. However, also the quality criterions have must also be discussed before a conclusion is made.

Table 5. The construct reliability and validity, and discriminant validity of the PLS path model

	Construct Reliability and Validity			**Discriminant Validity**			
	Cronbach's Alpha	**Composite Reliability**	**Average Variance Extracted (AVE)**	**Behavioural Intentions**	**DP knowledge**	**Gender**	**Perceived Risk**
Beh.Intentions	0.712	0.823	0.539	**0.734**			
DP knowledge	0.711	0.797	0.446	0.438	**0.668**		
Gender	1.00	1.00	1.00	0.092	-0.209	**1.00**	

	Construct Reliability and Validity			Discriminant Validity			
	Cronbach's Alpha	**Composite Reliability**	**Average Variance Extracted (AVE)**	**Behavioural Intentions**	**DP knowledge**	**Gender**	**Perceived Risk**
Perceived Risk	0.606	0.595	0.389	0.314	-0.057	0.11	**0.624**

According to Table 5 not all quality criterions for a sound PLS-models are met (Chin, 1998). Figure A shows that the item *Roach Motel* has loading of 0.578. This is below the threshold of 0.6 for items in exploratory studies. This is the reason why the average variance extracted, 0.446, is below the threshold of 0.5. If this item had been deleted, the quality criteria would have been met. Table 1 shows a low number (14%) on the question about explaining the expression roach motel. There are only three *Roach Motel* cards in the game, and not four or five as for the other dark pattern cards. The consequence is that in some games played by the students in this study, it is possible that none of the players got the *Roach Motel* card.

There is also an issue with the perceived risk factor. The (privacy) Zuckering item has an item-loading below 0.6, and the other items have loadings between 0.6 and 0.7. For a reliable measurement, the loadings should be at least 0.7. This is the reason why the composite reliability, a measurement for internal consistency, is below 0.6. The item named Zuckering could have been removed, but we decided to include the same types of items for the dark pattern knowledge and the perceived risk related to dark pattern activities.

4. Conclusion

Bellotti et al. (2013) write, "*Serious games are designed to have an impact on the target audience, which is beyond the pure entertainment aspect*." According to Zhonggen (2019), serious games are reported effective in education, but some studies arrive at negative conclusions. We used survey questions to measure the impact, if any, on the players of the Dark Patterns game. We conclude from the responses that the game had only a partial impact on the players' understanding and knowledge about dark patterns. The first research question (RQ1) was, *To what extent did the game convey the meaning of the types of dark patterns presented in the game to the players?* the players reported that they understand or can explain what the term means for only one of the dark pattern types - see table 1. One the other hand, knowledge about dark patterns matters. The PLS-SEM analysis shows that knowledge has a significant contribution in our model. The students with high dark pattern knowledge also report higher intention to take steps to protect their data. Of the three variables in the model, it is the most important and plays a role as moderator. We still conclude that RQ1 was not supported because most of the players stated that they could not explain the meaning of the dark pattern types.

The conclusion for the second research question is only based on the result of the PLS-SEM analysis. The analysis is exploratory in nature; we did not use constructs developed and validated by other researchers, but we developed questions specifically targeted to the types of dark patterns in the game. The second research question (RQ2) was, *To what extent are the players of the games' risk perception of data-sharing, (the harmful consequences of data-sharing together with the probability of dark pattern incidents) associated with the intention to protect personal data?* The PLS-SEM analysis shows a moderate association between the independent and dependent variables. In our model, dark pattern knowledge is the most important predictor followed by perceived risk. We conclude that RQ2 was supported.

The third research question, RQ3, was, *Is gender associated with the intention to protect personal data?* The PLS-SEM analysis showed that gender was not a significant predictor. Based on this result we conclude that RQ3 was not supported.

In the next phase of the research project on the dark pattern game, we will focus on students that have played the game several times. It is likely that a player that would like to win the game would need to practice, to play more than once. Then the player can make choices and think about which cards to play, and when. We think that a better approach to understanding the question of learning would be to use the score, the result of the game, together with the answers to survey questions, and after a player has played the game at least twice.

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Pure Gamification: An Energy Case

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Abstract: Dutch energy suppliers are obliged to cooperate in reducing consumption by stimulating energy saving behaviours among their customers. One important strategy for this context is personalized gamification. We investigate how a personalized gamified energy saving application can be designed based on individual preferences within the context of an energy supplier. To design a personalized gamification application the proposed method of Knutas et al. was adapted by leaving out the parts about machine learning and adding an evaluation phase. We show that customization by users can be a valuable alternative for using machine learning personalization strategies. We used this iterative design process to focus on personalizing, in this use case for the three main user types of the customer base of a Dutch energy supplier. The design of the gamified application was adapted using feedback of both stakeholders and customers using interviews and focus groups. This resulted in two final designs designed to stimulate energy saving behaviour among customers. The design had a dashboard which allowed for personalization within gamified elements, and an energy editor in which users can change characteristics in their households to learn about the effects of actions on their energy consumption. These two final designs were validated using an interactive prototype along with interviews. The added value of this study is that it shows that the Hexad framework with its proposed gamification user types is suitable to understand the main motivations of a target group. Results suggest that designing within gamified mechanics based on a user type's main motivation is an effective strategy for personalization. Motivation-based design is not the only successful personalization design strategy but adapting designs to personal situation and existing energy saving behaviour might also motivate users.

Keywords: Gamification; Personalization; Energy; Sustainability; Game based learning

1. Introduction

Since 2017, energy suppliers in the Netherlands are obliged to encourage energy savings among their customers (Rietkerk and Menkveld, 2017). In the advice given along with new legislation, gamification was cautiously mentioned as a tool for teaching people about and stimulating energy saving behaviour.

Gamification can be defined as *"the use of game design elements in non-game contexts"* (Deterding *et al.*, 2011), or *"a process of enhancing a service with affordances for gameful experiences in order to support users' overall value creation"* (Huotari and Hamari, 2012). It is used as a mean of supporting user engagement and enhancing positive patterns in service use, such as increasing user activity, social interaction, or quality and productivity of actions (Kankanhalli *et al.*, 2012). The concept of gamification consists of three subsequent elements, affordances implemented in a gamified system can lead to physiological outcomes which lead to further behavioural outcomes (Hamari, Koivisto and Sarsa, 2014). Affordances within gamification consists of elements that structure games and induce gameful experiences.

The recent interest into the potential and interest for gamification within the environmental contexts (Rietkerk and Menkveld, 2017), leads to more insights into the possibilities and effectiveness of gamified applications within this area. A literature review—on gamified applications designed to incentivize energy savings—showed average results from 4 up to 24% in energy savings within households (Iweka *et al.*, 2019). Personalized gamification within this context is more effective than one size fits all solution (AlSkaif *et al.*, 2018; Böckle and Kwaku, 2019; Böckle, Novak and Bick, 2020). Gamified applications that incentivize energy savings have already been applied in the commercial sector. Consumers can be engaged towards a more sustainable lifestyle (i.e. incentivize energy savings) by gamification (Morganti *et al.*, 2017; AlSkaif *et al.*, 2018; Wee and Choong, 2019). As researching such a real-life impact is difficult, storyboards with actual designs for prototypes can help to show how perceived persuasion of persuasive strategies are related to different user types (Böckle, Novak and Bick, 2020).

Building on these findings together with a more in-depth look at personalization in relation to energy suppliers described in section 2, we take the next step towards real-world implementation. In section 3 we describe our methodology for investigating how customizable dashboards can be designed. In section 4 we describe our first iteration of user research with lo-fi prototypes to investigate the potential of customizable and personalized gamification. In section 5 we present our final study with an interactive prototype to investigate how it could motivate energy saving behaviours within a commercial environment of an energy supplier. The results of the

evaluations are discussed within section 6 and in section 7 we provide the main take aways and conclusions. This whole study is conducted with actual customers of a Dutch energy supplier. The focus in this study is part of a bigger whole, earlier on we already investigated to what user type these customers belong (van der Neut, van Delden and Spil, 2022), in our current study we obtain first insights into the possibilities of personalized gamification for green energy suppliers, fitting the following research question:

How can we design a personalized gamified energy saving application based on individual preferences of users within the context of a green energy supplier?

2. Background theory and related work

Marczewski (2015) developed the Gamification User Types Hexad framework which highlights opportunities of personalization of gamification. The user types are not intended as mutually exclusive types but rather profiles where a person can be motivated fitting multiple types to a various degree. These types are described as follows

*"**Philanthropists** are motivated by purpose. They are altruistic and willing to give without expecting a reward.*
***Socialisers** are motivated by relatedness. They want to interact with others and create social connections.*
***Achievers** are motivated by competence. They seek to progress within a system by completing tasks, or prove themselves by tackling difficult challenges.*
***Free Spirits** are motivated by autonomy, meaning freedom to express themselves and act without external control. They like to create and explore within a system.*
***Players** are motivated by extrinsic rewards. They will do whatever to earn a reward within a system, independently of the type of the activity.*
***Disruptors** are motivated by the triggering of change. They tend to disrupt the system either directly or through others to force negative or positive changes. They like to test the system's boundaries and try to push further."*

(Tondello *et al.*, 2016):

Looking at the overall picture of energy saving applications several elements seem to be essential. Alskaif et al. (2018) suggested that the following five categories should be incorporated: information provision, rewarding system, social connection, user interface, and performance status. Beck et al. (2019) also mentioned feedback as an often used gamified category. An important category is the user interface, to have a positive effect on customer engagement the interface should not only be useful, but as well attractive and enjoyable to improve user experience (AlSkaif *et al.*, 2018; Beck, Chitalia and Rai, 2019).

At the moment, energy companies do not often make use of gamification in their energy feedback systems but instead use data and visualizations like graphs. However, there are many people who do not easily understand abstract numerical data about their energy usage (Karjalainen, 2011). One way to present data more clearly is with the help of metaphors. Melenhorst et al. (2018) and Koroleva et al. (2019) showed how to effectively apply metaphors for three main goals of energy saving, namely monetary, sustainable, and hedonic goals. In which monetary goals imply reducing costs, sustainable goals imply increasing environmental impact, and hedonic goals involve increasing someone's pleasure.

3. Methodology

Our global methodology for this study, see Figure 1, is based on the method proposed by Knutas et al. (2019). The sixth step named *'rapid prototyping'* follows a human-centred design process according to the International Organization for Standardization (ISO) (2010). Meaning that the target users participated in the design process from the very beginning in an iterative process. The user feedback and opinion of the stakeholders formed new input for this process in which changes were gradually introduced to optimize and improve the design, not all these steps fall within the scope of this paper.

4. Results

During the design ideation process, content, features and a first visual design strategy were created using existing theory on energy saving applications and preferences. Specifically, we included preferences of the user types achievers, free spirits, and philanthropists towards gamified elements and their expected behaviour within the environment of a green energy supplier. These were the three main user types among the customers of the

Dutch energy supplier (van der Neut, van Delden and Spil, 2022). Based on these findings we set up a design focus for each user type. Our first low-fidelity prototype was based on these user types and other inspirational sources but not yet considering style manuals etc. We used these for interviews with customers (*n* = 9) to discuss the responses to the various features. We then build a next iteration and gathered feedback from the client as well as through two focus groups (*n* = 4 & n = *6*). Based on this we build our final prototype.

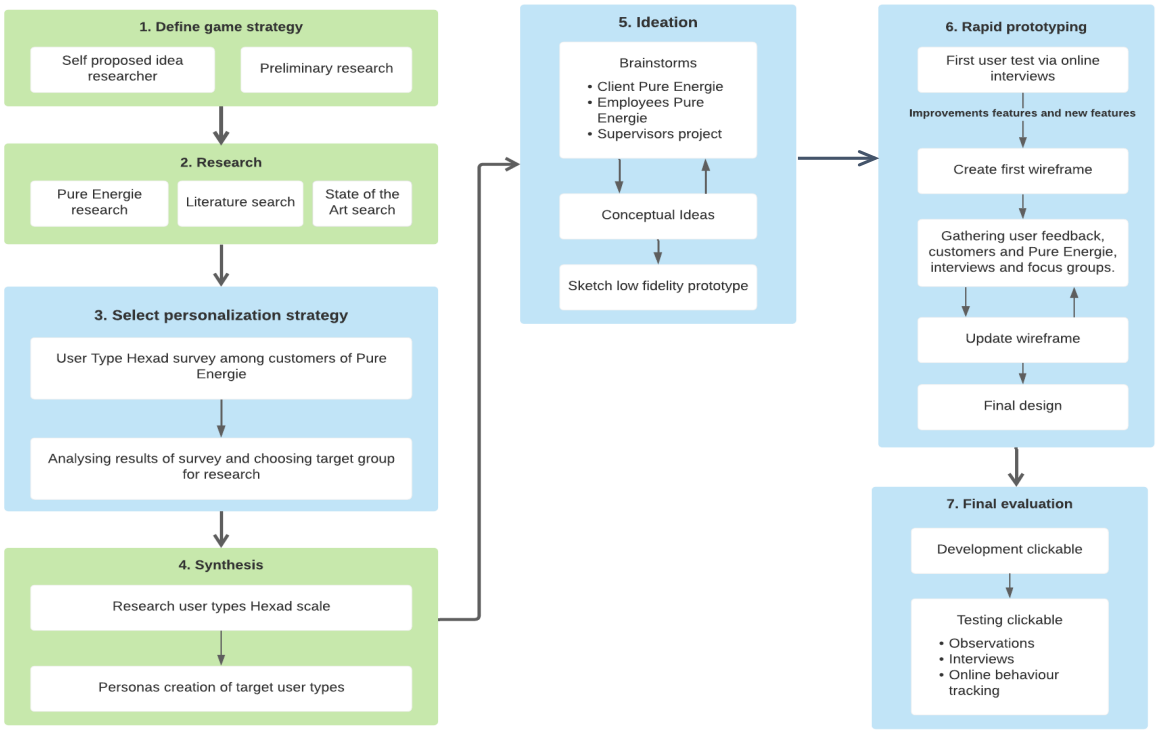


Figure 1: Overview of methos used during this project. Diverse methods were applied across seven different stages. The green coloured parts involved research performed in an earlier phase, in blue the parts of this current study

4.1 Differences towards gamification elements

An overview of the participating customers' motivation towards the different gamification elements is depicted in Table 1. The motivation towards the gamified elements is the way a participant indicated how they perceived it and how likely it is for them to use the functionality in a real-life application where –, +-, and + are respectively not likely, somewhat likely, and likely.

Table 1: Overview of motivations of the nine participants towards gamified elements based on our low-fidelity prototype

	Ach 1 ♀	Ach 2 ♂	Ach 3 ♂	Phi 1 ♂	Phi 2 ♂	Phi 3 ♀	Fr Sp 1 ♂	Fr Sp 2 ♀	Fr Sp 3 ♂
Points	+-	+	+	-	-	+-	-	+-	-
Hints	+	+	+	+	+	+	+	+	+
Feedback numbers	+	+	+	+	+	+	+	+	+
Profile	+-	+	+-	+-	-	+-	+	+	+-
Energy editor	+-	+	+-	+	+-	+	+-	+	+
Competitions	+	+	+	-	-	+	-	+	-
Comparisons	+	+-	+-	+	+	+	+-	+	+
Personalisation characters	+-	-	+-	+-	+-	+-	-	+	+
Challenges	+	+	+	+	+	+	-	+-	+
Levels	+	+	+	+-	+-	-	+	+-	-
Personalisation data	+	+	+	+	+	+	+	+	+
Metaphors	+-	+	+-	+	+	+	+-	+-	+-

4.2 Final prototype design

The final prototype design consists of a dashboard and an energy editor. The dashboard includes several different motivational affordances. Each affordance has multiple designs, allowing the participant to choose between the several elements during the final evaluation and create his or her ideal dashboard. Figure 3 shows the dashboard at the start in which some elements are not yet shown as the participant could choose the design option by clicking on the white boxes. The different design options for each element are listed in Table 2. For instance, Figure 2 shows the four final designs for the visual challenge. The second page forms the starting view of the energy editor, depicted in Figure 4. The energy editor has a menu which changes the top left block. Several elements have already been implemented in the house, showing what a situation could look like.

The different options for the gamified elements from Table 2 are designed for the three user types: achiever, free spirits, and philanthropists. It also shows the expected preferences of user types towards the game design elements. These expectations are based on the earlier gained results and the expected main motivation of each user type towards an energy saving application (van der Neut, van Delden and Spil, 2022). Meaning that achievers will be focused on competence and saving money, free spirits on autonomy, gain a lot of information and having fun, and philanthropists on increasing their own impact as they are motivated by purpose. For every element the accompanying goal is also described. *Metaphors* allow for comparing energy savings with information more understandable for individuals. *Comparisons* allow for comparing your energy consumptions compared to different categories. *Profile* shows a user's name, and the user can choose a profile picture by creating a character, choosing a location, or adding a picture. The *visual challenge* is coupled to points in the design and allows for playing for something interactive and growing within this challenge. *Challenge's goal* consists of goals and the type of challenge. Goals can help individuals to increase savings and receive feedback, challenge types are different approaches to start energy saving behaviour. *Ranking* is done via a leader board which can show your position compared to friends, the region, or all customers. The *"Learn more"* is to trigger users about learning about their energy usage and this can be done through a quiz, hint or "Did you know?" approach. The *level* can be shown as number or in a progress bar. Lastly, *badges* can be shown per three or only showing the last badge.

5. High-fidelity prototype final evaluation

The final design was developed within Axure, which allowed for creating an interactive prototype that could be shared online and connecting Hotjar[1]. Hotjar is a is a tool to get insight into how visitors are using a website and to collect user feedback. In total fifteen customers participated. For each user type (philanthropist, achiever, or free spirit as main user type) we selected three males and two females. We held a semi-structured interview via Microsoft Teams. Looking at the average clicking behaviour we clearly saw that free spirits (199) performed more clicks than philanthropists (123) and achievers (122). Supporting our expectations and suggesting they explore the application. Free spirits were interested in what was behind each element and whether there was more information for both the dashboard and energy editor: *"what does this show or do"* was a typical quote. Free spirits also choose more different options than the other user types.

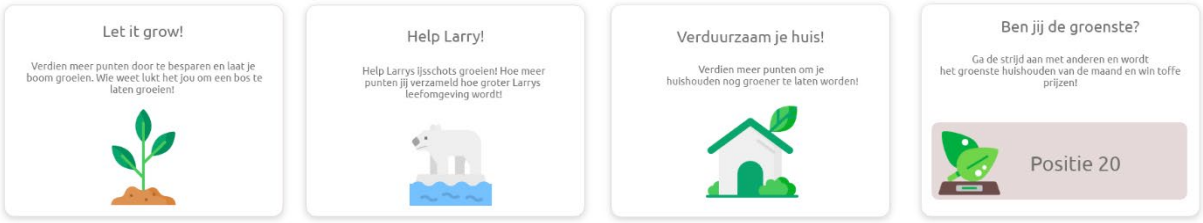


Figure 2: Final designs of interactive visual challenge game element mostly in Dutch, including *Let it grow*, *Help Larry!*, *Make your house more sustainable!* and *Are you the most green?* (i.e. durable)

[1] Hotjar, basic version, https://www.hotjar.com/

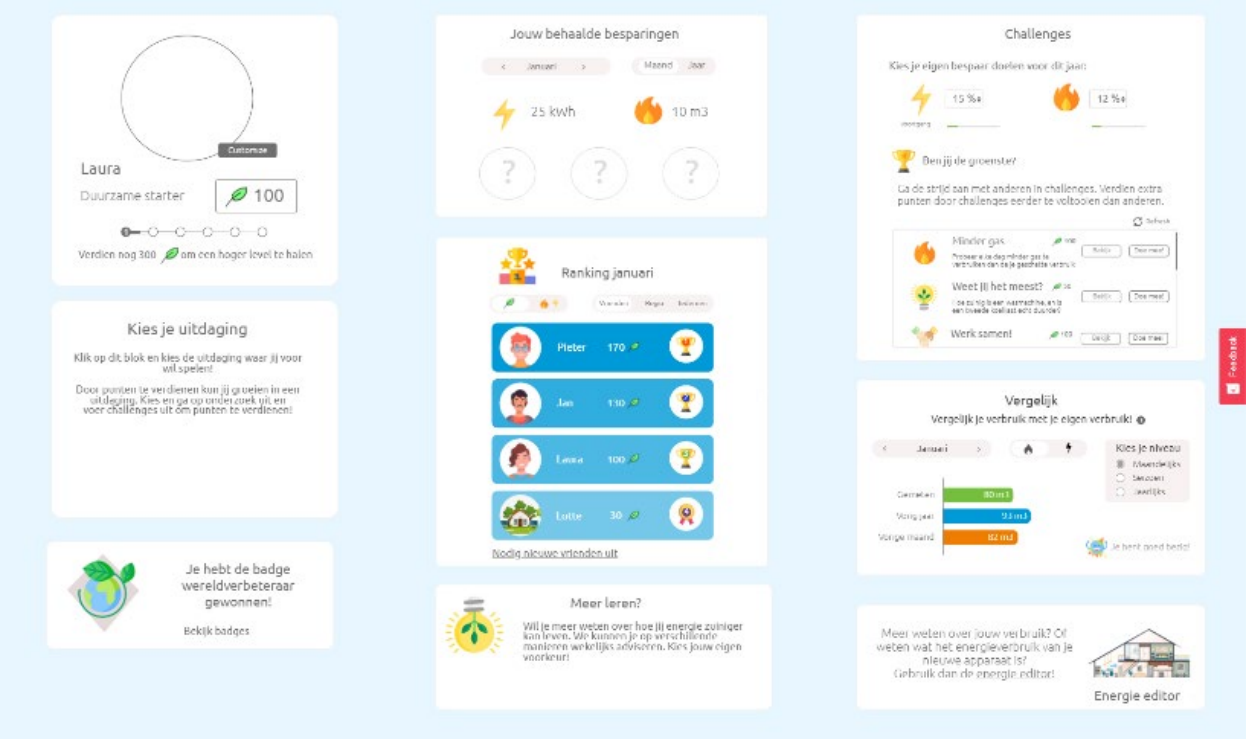


Figure 3: Final wireframe design of the dashboard. The following elements are included: a description of the profile, choosing a challenge, badges, achievements, leader board, an overview of open and completed challenges, comparing use, and a link to an energy editor (see Figure 4).



Figure 4: Final design of the energy editor. The proposed overview dashboard has four elements: overview, game progress, settings, and learn more. The solar panel character hints to investigate how you can save energy and find the most energy consuming household items. In the top right several changes can be simulated (e.g. adding solar panels, lowering the thermostat, or an electrical car)

As expected, the most obvious differences between user types are visible within *"challenge type and goal"*, *"learn more"*, *"ranking"*, and *"visual challenges"*, see Table 2. We did not expect philanthropists would choose

elements about money. However, this happened for both the metaphors and challenge goal. The philanthropist choosing for this explained that you can directly relate to money and understand this easily. However, the focus of this participant was still saving energy and they did not have a big monetary focus: *"I easily understand the concept of money, although saving money in the case of energy usage is not a motive for me*". This might suggest that even though a metaphor or depiction might be related to a specific motivation, the underlying mental model can be different. In this case for metaphors and goals involving a monetary focus as it provides a comprehensible comparison between saving money and saving energy.

The designs involving competition scored highest for the achievers. The challenge involving competitions was even only chosen by achievers. There are also some unexpected choices, such as a philanthropist choosing an element matching competition, or the earlier mentioned money. This might be explained by users forming a spectrum of user types and not just depending on a single motivation. For example, for the profile of the philanthropist choosing the elements involving price, the achiever type scored second highest. Although participants from certain user types sometimes made different choices for designs deviating from the expectations, their main motivation was still the same as the motivation of their main user type.

Finally, we observed that every user would like to change the energy editor to his or her personal home situation. These results suggest that designing for personal situation is important: *"It is really interesting if you could simulate your own household if this allowed for more comprehensive and personal advice on energy savings, it would even be better if it takes into account the measures that I already take*". This also implies that not only personal home situation is an important personalization factor, but also existing environmental behaviour, which was supported by the answers of multiple participants.

Table 2: Chosen designs in dashboard during final evaluation by user types (*n* = 15, 5 per user type)

Metaphors	Piggybank money	Number of trees	Kg of Co2	Generation time windmill	Performance against others	km car ride
Achievers	**33,33%**	16,66%	16,66%	-	**33,33%**	-
Free spirits	**26,66 %**	13,33 %	13,33%	20%	13,33%	13,33%
Philanthropists	8,33 %	**33,33%**	**33,33%**	-	8,33 %	16,66%
Comparison	Own usage	Households region	Friends	Comparable household	Other type households	
Achievers	-	**50 %**	16,66%	16,66%	16,66%	
Free spirits	**38,46%**	15,38%	7,71%	23,07%	15,38%	
Philanthropists	**50%**	-	-	**50%**	-	
Profile	Character	Google maps	Character house	Upload own picture		
Achievers	25%	-	-	**75%**		
Free spirits	-	-	20%	**80%**		
Philanthropists	**75%**	-	25%			
Visual challenge	Larry ice bear	Plant growing	Competition	Make sustainable house		
Achievers	-	25%	**75%**	-		
Free spirits	**60%**	20%	-	20%		
Philanthropists	25%	**50%**	-	25%		
Challenge's goal	kWh and m3 in %	Euros In %	No goal			
Achievers	-	**75%**	25%			
Free spirits	**100%**	-	-			
Philanthropists	**50%**	25%	25%			
Ranking	Friends	Region	All customers			
Achievers	**100 %**	-	-			
Free spirits	20%	20%	**60%**			
Philanthropists	25%	**75%**	-			
Learn more	Did you know that	Quiz	Hint			
Achievers	-	**75%**	25%			
Free spirits	**80%**	20%	-			
Philanthropists	-	**50%**	**50%**			

Challenge type	Are you the greenest	Save for impact	Create own challenge
Achievers	**75%**	25%	-
Free spirits	-	20%	**80%**
Philanthropists	-	**100%**	-
Level	Progress bar	Mystery level	
Achievers	**100%**	-	
Free spirits	**60%**	40%	
Philanthropists	**100%**	-	
Badges	Show last 3 badges	Show last badge	
Achievers	**50%**	**50%**	
Free spirits	**60%**	40%	
Philanthropists	**75%**	25%	

6. Discussion

6.1 Adapted method for designing personalized gamification

The method applied in this study is based on the proposed method by Knutas et al. (2019) for machine learning based personalized content selection. We selected this method due to our interest in future automatization and the model's overarching overview while also connecting personalization to the Hexad framework. However, the findings of this research did not yet focus on applying machine learning for personalization, but on customization by the user for personalisation. Therefore the method was adapted leaving the parts focusing on the machine learning algorithm. Furthermore, we added a novel final step, namely the final evaluation phase to be able to validate the design and final hypothesis. Lastly, we advise to follow a human centred design approach (I. O. f. Standardization, 2010) for iteratively improving the gamification designs during the ideation phase. This study suggests that this adapted method is effective to create personalized gamification by allowing the user to customize their own gamification solution. Future work could investigate whether a population for a specific gamification design prefers choosing their own gamification designs as done in this study or rather would want to have a suitable gamification design provided by an algorithm or a mix of them.

6.2 Motivation-based personalized gamification or element-based personalization

The results of this study aligns with earlier findings from the literature, that personalized gamified solutions can be more effective than one-size fits all approaches (Deterding, 2014; Tondello *et al.*, 2016; Orji, Oyibo and Tondello, 2017; Mora *et al.*, 2018). The different preferences of the participants for gamification elements and their preferred focus show that personalization is a key feature to make an energy saving application fitting for an individual. However, participants were only confronted with interactive pages and not long-term preference or behaviour, leaving room for future work.

The Hexad scale building on Marczewski's Gamification User Types Hexad framework (Tondello *et al.*, 2016) was designed to understand more about user psychology in a gamified context. However, correlation analysis also showed the usefulness of the Hexad model as measure of predetermined design elements (Tondello *et al.*, 2016, 2019). Research on the Hexad scale for stimulating energy saving behaviours also suggested that the Hexad model can indicate the preference of end-users towards specific gamification design elements (Böckle, Novak and Bick, 2017; Kotsopoulos *et al.*, 2018). In general, personalization with use of the Hexad scale is often performed through applying different gamification elements for each user type (Osbaldiston and Sheldon, 2003; Tondello, Mora and Nacke, 2017; Kotsopoulos *et al.*, 2018; Wee and Choong, 2019). However, this study showed a different approach for personalization within a gamified application, namely a motivation-based approach instead of the often-used element-based approach. Designing within a specific element based on the main motivation of an end-user was proven to be successful showing that within a gamified application personalization can be applied in another way as well. As participants preferred game mechanic designs matching their motivation behind using an energy saving application, we suggest that this is a suitable approach for personalized gamification in an energy saving context. As the main motivation of a user type forms the attitude and expectations towards a gamification solution, designing for this motivation can also be applied in other contexts rather than only for an energy saving goal. However, this finding does not contradict successful use of the Hexad scale in relation to element-based personalized design and it still helps to understand the psychological motivations of individuals and therefore could inspire a fitting design space.

Although most participants acted as expected during the final evaluation, some choose designs that were not matching the expected preference of their main user type. A possible explanation for this can be that individuals form a spectrum of users which can make them interested in motivations of other user types as well (Tondello *et al.*, 2016). Van Houdt et al. (2020) findings even suggest that particularly intrinsic motivations towards the environment predict preferences for gamification strategies whereas user types fall short. However, their research made use of one design version with different gamification elements and looked at how different user types interacted with the design. Meaning that there was not such a design approach as designing specifically for a user type. Based on our results we do not agree that the user types of the Hexad scale fall short in predicting gamification strategies, as the model helps to explain the main motivation of users within an energy saving application.

7. Conclusion

We iteratively designed personalized gamified solutions based on user feedback. Different from previous research indicating that using different motivational affordances per user type allows for personalization, this research suggests that motivation-based designs within a gamified element is an effective personalization approach for an energy saving application. For our study regarding philanthropists, this comes down to designing for purpose which can be incorporated by giving them insight in their own impact and by allowing them to increase their impact. Where achievers have a need for competence which they want to see back in energy saving applications through competitions with others, mostly with friends. Lastly, free spirits are motivated by autonomy, resulting in designing for having fun and learning about energy savings by allowing multiple options instead of one single defined route.

The iterative design process for personalization resulted in a gamified design consisting of two pages. It contains a dashboard and energy editor tailored towards a customer portal of a green energy supplier. Customers can choose the look of their dashboard by choosing between the different designs for each game mechanic. The energy editor can be adjusted to a customer's home situation and shows where energy savings can be reached or what decisions will cause extra usage. We see allowing users to choose between different designs for the elements on the dashboard fits with a feeling of autonomy. Although autonomy is most important for the user type free spirits, philanthropists and achievers were also liking the opportunity to create their own environment. This fits with autonomy being an intrinsic need which to various degree is an important motivator for each of the three user types.

Personalization cannot only be achieved by designing for different motivations of user types, but also by adjusting designs to match personal situation and already existing energy consumption behaviour. This approach gives users the feeling that the application is really giving them personalized advice. Furthermore, building on related work the elements information provision, progress, interactive user interface, and feedback were found essential within an energy saving application. They help to create a basic understanding within an energy saving application and increase user involvement.

This research with actual customer of a green energy supplier provides a broader view into the possibilities of personalized gamification design for an energy saving application. The findings of this research propose a method on how to introduce the technique of gamification in such organisations and a framework that describes the main user types present and how to design for them.

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Literacy Educators' Attitudes on Video Games and Learning

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Abstract: This research used a survey design methodology (Dillman, 2011), which is a "nonexperimental research based on questionnaires or interviews" (Johnson & Christensen, 2013, p. 249) to investigate elementary literacy teachers' attitudes on video gaming and learning. 328 teachers from a Midwestern state in the United States completed a 37-item survey, which primarily utilizes five-point Likert scale items to examine their general perceptions of video games, their attitudes on video game-based learning, and their perspectives on utilizing games for literacy teaching and learning. The data were analyzed by examining the distribution and frequency of participant responses as well as overall trends in their perspectives (Iarossi, 2006). Results indicate that the teachers believe children enjoy playing video games, view games as an important aspect of youth culture, and generally believe that video games can promote student motivation, engagement, and learning. However, only 38% of participants either agreed (32.0%) or strongly agreed (4.6%) that they regularly integrated video games into their literacy teaching and approximately a third were skeptical about integrating video games into their literacy teaching (26.8% agreed and 7.3% strongly agreed). Additionally. 57% were interested in learning more about how to effectively integrate video games into their literacy teaching (47.9% agree and 10.1% strongly agreed). This finding makes sense given that only 14% of participants indicated they learned about digital game-based learning during their teacher preparation programs. Ultimately, participants' positive views on learning through video games aligns with existing reviews of research that demonstrate the effectiveness of game-based learning in a variety of content areas (Clark et al., 2016; Thompson & von Gillern, 2020; Wouters & van Oostendorp, 2013). Given that teachers' views largely align with research that demonstrates games can be effective at promoting student learning in a variety of disciplines, professional development is needed to help teachers develop their abilities to effectively integrate video games into their literacy teaching. Further implications and directions for future research are discussed.

Keywords: Video games, literacy, learning, teachers, survey

1. Introduction

Stemming from the work of the New London Group (1996), today's educators recognize the role of digital literacies as part of language arts instruction. Literacy practices continue to expand alongside evolving definitions of literacy, particularly in terms of the multiliteracies that are prevalent in the digital age. In recent years, teachers have evidenced through their pedagogical approaches this expanding view of literacy by including new literacy practices and technologies in the classroom (Kalantzis et al., 2016). Students of the 21st century regularly interact with – both consuming and producing – texts that are multimodal in nature (Serafini, 2015), and teachers recognize the importance of incorporating technology into the classroom and supporting students as they layer meanings across multimodal texts (Abrams & Gerber, 2015). While teachers often include audio and video media in ELA classrooms, the use of video games in classroom settings has been slower to gain traction as an established practice.

Video games can support learning related to a variety of cognitive processes such as inductive reasoning (Greenfeld, 2014) and decision-making (Gros, 2007). Further, video games can be used in classroom contexts to support learning (Clark, Tanner-Smith & Killingsworth, 2016), including within language arts instruction (Beavis, 2012; Gee, 2007; von Gillern et al., 2022). In ELA classrooms, video games can be used to teach varied literacy standards (Marlatt, 2018;

Stufft, 2018; Stufft & von Gillern, 2021) and to promote students' critical thinking and metacognition (von Gillern & Stufft, in press).

Video games are commonplace in the lives of today's youth. Over 90% of children in the US play video games regularly, and the vast majority of US adults (75%) also engage with this medium (NPD Group, 2020). Video games are immensely popular within youth culture, and teachers recognize that the use of video games in the classroom provides a way to engage students (Beavis, Dezuanni & O'Mara, 2017). However, video games have not made their way into mainstream use in classrooms or as a standard part of ELA curricula as of yet.

2. Literature Review

Video games have been described as powerful learning tools that require players to respond to simulated environments, progressively developing new knowledge and skills within game worlds (Gee, 2007; Pelletier, 2009). Engagement with games requires complex thinking and skills, including planning, problem solving, collaboration, adaptive thinking, and technical abilities (Federation of American Scientists, 2006). Squire (2014) identified six practices of gamers that allow for learning in social contexts, including, for example, producing and consuming information, strategic use and critique of digital spaces, and multimodal meaning-making. McClarty et al.'s (2012) review of gaming for educational purposes reaffirmed the role of learning principles within games, highlighting games' particular affordances in relation to engagement, personalized learning, digital skills, and authentic assessment. The question facing researchers today is not whether games can serve as rich sources of learning, but how to leverage the affordances of gaming in school contexts (Beavis et al., 2017).

Research on the use of video games in classroom settings has highlighted a multitude of curricular implementations in literacy instruction, including game analysis (Bacalja, 2018), multimodal composition (McClay et al., 2007), and collaborative problem solving and design work (Gerber et al, 2014). These diverse forms of curricular implementation have been shown to have positive impacts on student learning (Nash, 2022). Across settings, researchers have reported increases in student engagement (Gerber et al., 2014), shifts in students' academic identities (Marlatt, 2018), complex analytical thinking (Beavis et al., 2015), and students engaged in multimodal design thinking and composition (Nash 2021a; Stufft & von Gillern, 2021).

Despite promising findings in the extant research literature, myriad challenges and obstacles remain for incorporating games into classroom spaces (Burn, 2004). Video games have long been stigmatized in K-12 and university settings (Murray, 1997), though this perception has been changing; a recent review of research on games in literacy found that few empirical studies of game-based learning had been conducted prior to 2005, meaning that the research base around which to ground curricular implementation remains nascent in comparison even to other forms of new media, meaning that teachers have fewer curricular resources and less of a research base to justify their decisions about gaming in classrooms (Beavis & O'Mara, 2010). Moreover, implementing video games requires teachers to synthesize between analytical traditions within the discipline of language arts (Skerrett & Warrington, 2018) and an interactive form of media that demands explicit player interactivity (von Gillern, 2016; Beavis et al., 2014). Many games have playtimes that exceed 100 hours, presenting teachers with questions about how often to play games versus to analyze them, a question made more difficult by the deficit attitude towards game-based learning in most schools.

Researchers have posed legitimate questions as to how much knowledge of a new medium is required to teach and teach with it in classroom spaces, posing questions related to educational co-optation of digital literacies and the proper relationship between traditional school-based literacies and those students commonly take up outside of school (Alvermann & Heron, 2001). Given both the promise and the challenges that face teachers and curriculum designers interested in game-based learning, it remains important to consider teachers' perspectives on the use of video games in the classroom. Extant research has shown that teachers' perceptions and conceptualizations of video games play a large role in whether and how students are provided opportunities to engage in these new literacies (Beavis et al., 2017). As Beavis et al. (2014) explain, "teachers' beliefs about what it is (or is not) possible to achieve with digital games in educational contexts will inevitably influence the decisions that they make about how, when, and for what specific purposes they will bring these games into their classrooms" (p. 569).

Thus far, there is only scant research available regarding teachers' views of video game implementation, in part owing to the fact that much of the empirical work surrounding game implementation in literacy classrooms comes from qualitative, ethnographic studies that utilize purposive sampling; this work, though it often includes contextualized descriptions of teachers' views, is not meant to represent the views of a broader teaching public, but rather to highlight the possibilities of game-based learning in specific classroom contexts (Authors, 2022; Beavis et al., 2017).

Studies that have explicitly examined teachers' views have found a mix of caution and excitement related to games (Can & Cagiltay, 2006). Beavis et al. (2014), for example, in a study of Australian teachers' views of gaming, found that many teachers were intrigued by the possibility of introducing engaging texts that allowed for virtual exploration and problem solving. This optimism was common across their study participants; the concerns related to gaming were more diverse and idiosyncratic to individuals, and included a lack of self-efficacy regarding gaming knowledge, a fear of losing control over classroom learning time, and concern for how to manage differential knowledge and experience with games among students. Gerber and Price (2013), in a study of American teachers enrolled in a graduate course, showed that although the teachers were excited about the possibilities of game-based learning, they also worried about (1) the cultural stigma that was attached to gaming being applied to their professional identities as teachers and (2) the logistical hurdles to including games in classroom-based settings. Although there have been several studies of teachers' perceptions of video game-based learning in disciplines such as physical education (Jenny et al., 2013), science education (Marino et al., 2013), and secondary language arts (Chik, 2011), there have been no recent large-scale examination of teachers views of gaming and game-based learning in relation to literacy education, and few studies on this topic in the last decade.

With both technologies and attitudes towards gaming and other new literacies rapidly shifting (Leu et al., 2013), it is imperative that researchers, educators, and curriculum designers develop comprehensive and up-to-date knowledge of teachers' understandings of video games in relation to classroom learning.

3. Methodology

A survey design methodology (Dillman, 2011), which is a "nonexperimental research based on questionnaires or interviews," was utilized for this study (Johnson & Christensen, 2013, p. 249) to answer the following research question: What are elementary literacy teachers' attitudes on video gaming and learning?

The survey was designed by reviewing existing surveys and concepts from the literature that aligned with the research question. Items from Homer et al.'s (2012) Demographics, Attitudes, and Player Activity (DAPA) survey and Noraddin and Kian's (2014) survey on digital games for teaching and learning were included in the present survey. Some items were modified for clarity and to become tailored to the target audience of this study (i.e., literacy teachers). For example, Homer et al.'s study was developed to be given to children, and thus, we modified some items to shift to a format appropriate for the target audience (e.g., the survey item "I spend too much time on video games" was changed to "Children spend too much time on video games"). Furthermore, the researchers created new items aimed to develop an understanding of the research question (e.g., "Integrating digital games into the classroom can promote student motivation" and "Digital games are a form of media worthy of analysis in English language arts classrooms"). A panel of four experts as well as four teachers reviewed the survey questions and provided feedback on the content and clarity of the survey items. This feedback was used to refine the survey's clarity and create additional items aligned with research goals to create a final survey with 37 items that examine their general perceptions of video games, their attitudes on video game-based learning, and their perspectives on utilizing games for literacy teaching and learning. The survey consists primarily of five-point Likert scale items and also includes demographic items.

The survey was distributed to literacy teachers in a Midwestern state in the United States through email distributed via Qualtrics. Over the following two weeks, three reminder emails were sent as well. In total, 328 elementary literacy teachers completed the survey (see participant demographics in Table 1). Any survey that did not have 100% of items completed was excluded from analysis. The data were analyzed by examining the distribution and frequency of participant responses as well as overall trends in their perspectives (Iarossi, 2006).

4. Results

Results (see Table 2) indicate that the teachers believe children enjoy playing digital games (97.6%) and view games as an important aspect of youth culture (72.2%). While teachers note the high levels of enjoyment and relevance for youth culture, they also believe that "children spend too much time playing digital games" (75.6%). Though, they also believe that "it is fine for children to play digital games as long as it doesn't negatively affect their schoolwork" (74.4%). These results indicate that teachers generally recognize the importance of digital games for children; however, they have concerns about children spending too much time playing games.

Table 1: Participant Demographics

Age	
20-30	15.6%
31-40	27.8%
41-50	33.0%
51-60	19.2%
61+	4.6%
Years Teaching Experience	
0-5	25.6%
6-10	16.5%
11-15	11.9%
16-20	15.2%
21-25	18.6%
26+	12.2%
Grade Level Taught	
K-3	30.5%
4-6	25.0%
Specialist / Other	44.5%
Gender	
Female	93.0%
Male	5.8%
Non-Binary / Third Gender	0.3%
Prefer Not to Say	0.9%
District Type	
Rural	48.8%
Suburban	35.7%
Urban	15.5%
Hours of Digital Games Currently Played Per Week	
Zero	35.7%
0.1 to 2.9 Hours	47.0%
3 to 5.9 Hours	12.8%
6 – 8.9 Hours	4.0%
More than 9 Hours	0.6%
Hours of Digital Games Played Per Week when Same Age as Current Students	
Zero	54.3%
0.1 to 2.9 Hours	30.8%
3 to 5.9 Hours	11.0%
6 – 8.9 Hours	3.4%
More than 9 Hours	0.6%

In terms of teachers' attitudes on games and learning, the teachers generally believe that video games can promote student motivation (87.2%), engagement (87.8%), and learning (74.7%). Additionally, most participants believe that playing digital games requires "players to engage in complex thinking and learning processes" (62.2%). Teachers also agreed that "digital game-based learning will be an important teaching tool in the years to come" (78.1%), and "digital games can teach children valuable information they might not learn in school" (67.7%).

In terms of games and literacy instruction and development, slightly over half believed that digital gaming is a digital literacy practice (57.9%), yet the vast majority believed that "teachers can use digital games to enhance student learning in English language arts (82.3%).

However, only 36.6% of participants regularly integrate video games into their literacy teaching and approximately a third were skeptical about integrating video games into their literacy teaching (34.1%). Additionally. 57% were interested in learning more about how to effectively integrate video games into their literacy teaching (47.9% agree and 10.1% strongly agreed). This finding makes sense given that only 14% of participants indicated they learned about digital game-based learning during their teacher preparation program.

Table 2: Survey Results

Survey Item	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean Score
Q1 - Digital games make children feel good about themselves.	3.7%	7.9%	42.4%	42.7%	3.4%	3.34
Q2 - It is fine for children to play digital games, as long as it doesn't negatively affect their schoolwork.	2.7%	8.8%	14.0%	66.2%	8.2%	3.68
Q3 - Children spend too much time on digital games.	1.2%	6.7%	16.5%	47.9%	27.7%	3.94
Q4 - Playing digital games is a waste of time.	6.7%	61.6%	25.9%	4.6%	1.2%	2.32
Q5 - Spending money on digital games is a waste.	5.5%	53.4%	22.9%	13.7%	4.6%	2.59
Q6 - Most children like to play digital games.	0.3%	0.3%	1.8%	54.6%	43.0%	4.40
Q7 - Digital games help children make friends in school.	7.3%	27.1%	32.6%	31.7%	1.2%	2.92
Q8 - Digital games are an important part of youth culture.	3.0%	10.1%	14.6%	58.2%	14.0%	3.70
Q9 - Using digital games is useful for student learning.	1.8%	7.9%	15.5%	67.1%	7.6%	3.71
Q10 - Using digital games for instructional purposes creates a student-centered learning environment.	4.3%	15.5%	18.6%	54.9%	6.7%	3.44
Q11 - Digital game-based learning will be an important teaching tool in years to come.	2.7%	5.5%	13.7%	60.4%	17.7%	3.85
Q12 - I am doubtful about the benefits of using digital game-based learning.	7.3%	53.0%	15.2%	17.4%	7.0%	2.64
Q13 - Digital games can teach children valuable information they might not learn in school (e.g., about the military, country names, world history).	2.4%	12.8%	17.1%	60.4%	7.3%	3.57
Q14 - Digital games help children learn to be team-players.	7.9%	28.7%	25.0%	32.6%	5.8%	3.00
Q15 - Digital games allow children to experience what it is like to live like someone else.	7.0%	28.7%	32.0%	30.2%	2.1%	2.92
Q16 - Integrating digital games into the classroom can promote student motivation.	1.2%	2.7%	8.8%	70.4%	16.8%	3.99
Survey Item	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Mean Score**
Q17 - Integrating digital games into the classroom can promote student engagement.	1.5%	3.7%	7.0%	66.5%	21.3%	4.02

Survey Item	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean Score
Q18 - Playing digital games requires players to engage in complex thinking and learning processes.	1.8%	9.8%	26.2%	54.6%	7.6%	3.56
Q19 - Digital gaming is a digital literacy practice.	6.1%	12.2%	23.8%	52.4%	5.5%	3.39
Q20 - Teachers can use digital games to enhance student learning in English language arts.	1.8%	4.9%	11.0%	73.2%	9.1%	3.83
Q21 - Digital games are a form of media worthy of analysis in English language arts classrooms.	2.7%	8.5%	20.4%	58.5%	9.8%	3.64
Q22 - It is valuable to provide a space in English language arts classrooms for children to discuss digital games in a similar fashion to how they discuss books, movies, and other forms of media.	4.6%	18.6%	27.1%	44.5%	5.2%	3.27
Q23 - Digital gaming requires players to interpret multiple modes of communication (e.g., visual, written, and oral information).	1.2%	9.8%	13.1%	67.4%	8.5%	3.72
Q24 - Teachers can effectively incorporate activities related to digital games into their English language arts instruction (e.g., having students write game reviews, create how-to guides, etc.).	2.1%	3.4%	9.1%	71.3%	14.0%	3.92
Q25 - I regularly integrate digital games into my English language arts instruction.	15.2%	36.0%	12.2%	32.0%	4.6%	2.75
Q26 - I am skeptical about integrating digital games into my English language arts instruction.	7.3%	40.9%	17.7%	26.8%	7.3%	2.86
Q27 - I am confident in my abilities to effectively integrate digital games into my English language arts instruction.	7.6%	25.3%	22.6%	37.8%	6.7%	3.11
Q28 - I want to learn more about how to effectively integrate digital games into my English language arts instruction.	6.4%	14.3%	21.3%	47.9%	10.1%	3.41
Q36 - I learned about digital game-based learning in my teacher preparation program.	41.8%	38.7%	5.5%	12.5%	1.5%	1.93
Q37 - I am confident in my abilities to effectively integrate educational technologies into my English language arts instruction.	3.4%	17.1%	17.4%	51.5%	10.7%	3.49

5. Discussion

The results can generally be broken into three sections including 1) teachers' general perspectives on video games and children, 2) their views on game-based learning, and 3) their perspectives on utilizing video games in English language arts teaching. In terms of their general perceptions on video games and children, the teachers' attitudes were positive in that they believed video games were an enjoyable and important part of youth culture. While they had concerns about children spending too much time playing video games, the teachers recognized that children enjoy games and it is fine for them to play them as long as it doesn't negatively affect their schoolwork.

Additionally, the teachers' views on game-based learning were positive and they believed that video games can support student motivation, engagement, and learning and that "digital game-based learning will be an important tool in years to come." A notable finding in this group of results is that only 32.3% of teachers felt that "digital games allow children to experience what is like to live like someone else." This is an interesting finding given that many video games require the player to assume the role of a digital avatar, and players need to think and act accordingly.

These avatars often have a backstory and serve as a person for the player to embody and control during gameplay, a process and experience documented in research on game-based learning. For example, in his foundational work, Gee (2007) identified how games promote learning through the principle of identity, in which "learners need to know what the 'rules of the game' are and who plays it. They need to know how to take on the identity...[and] operate by a certain set of values, attitudes, and actions" (p. 32). This idea also relates to Prensky's (2005) video game learning principle of role playing. Thus, given that research indicates that video gaming does allow people to "experience what it is like to live someone else", this could be communicated to teachers in professional development programs, particularly given the affinity literacy teachers have for stories and characters.

While the literacy teachers' attitudes on gaming and children and game-based learning were generally positive, their perspectives on utilizing video games in literacy teaching were more mixed. For example, the teachers agreed that video games can support learning in English language arts classrooms, less than 60% believed that digital gaming is a digital literacy practices, and less than 50% believed it was "valuable to provide a space in English language arts classrooms for children to discuss digital games in a similar fashion to how they discuss books, movies, and other forms of media." Additionally, only 36.6% agreed they "regularly integrate digital games into [their] English language arts instruction. Thus, there is a disconnect between their generally positive perceptions that video games can support student learning, including literacy learning, and their willingness to provide time for such activities in their own classrooms. While the present research did not deeply investigate this disconnect, this phenomenon may be influenced by the fact that over 80% of teachers indicated they did not learn about digital game-based learning in their teacher preparation program.

Additional insights into this disconnect may be gleaned from the literature. For example, one barrier for teachers who do consider the use of video games as part of teaching and learning is the fear of being ostracized by administration, colleagues, and/or parents for including video games in the classroom; additionally, teachers face challenges in terms of funding for and technological support for video game software and hardware in classroom spaces (Gerber & Price, 2013). Also contributing to whether teachers use video games in their classrooms is the extent of prior experience teachers themselves have had with video games. Teachers who do not feel comfortable with video games or those who have limited knowledge of video games and/or limited experience playing video games are less likely to incorporate video games into their teaching (Beavis et al., 2014). Collectively, these lead to a disconnect between the prevalence of video games in the lives of students and the inclusion of video games in classrooms.

The findings build on existing research highlighting contrasting attitudes on the part of teachers in relation to video game-based learning. Although no larger surveys have examined the views of elementary teachers, smaller qualitative studies of teachers' views (Gerber & Price, 2013) and studies focusing on secondary teachers (Beavis et al., 2014) have highlighted the recurrence of positive views of gaming as a literacy practice, but hesitations regarding the incorporation of games in schools. The results in this study suggest that the concerns reported by populations such as secondary language arts teachers' and university graduate students apply in the context of elementary literacy instruction as well, with teachers across contexts and who work with myriad age groups reporting excitement about the possibilities posed by digital games, while also expressing hesitation regarding the implementation of games in school settings.

These results highlight that even when teachers have positive views of gaming or perceive gaming as a form of digital literacy, inclusion in school curricula presents a separate challenge for the progress of video game-based learning curricula. Studies of practicing teachers and teacher candidates learning about digital and multimodal literacies have emphasized the challenges that accompany developing new conceptions of literacy in school contexts beyond the print-based traditions that have historically been dominant in schools and in literacy curricula specifically (Nash et al., 2021). Such concept-building requires paradigm shifts in thinking about the nature and boundaries of the profession in which teachers are engaged and does not necessarily come easily or without extended learning experiences (Kist & Pytash, 2015).

Existing research has highlighted that not only are video games not explicitly supported in school-based literacy curricula, they are often actively discouraged through myriad technological, logistical, and ideological challenges

unique to school settings (Nash, 2022). Thus, the kinds of conceptualization and understanding required to be comfortable considering games for in-class use may be harder to develop in relation to games than other digital and multimodal literacies. Lastly, the concerns of teachers about games in classroom settings reported here may also reflect the increasing dominance of standardized curricula across North America (Parker, 2020) that increasingly removes the ability of educators to act as agentive designers of their own curricula.

This being said, the results of the study, in conversation with existing research, point to powerful possibilities for future incorporations of video games in literacy classrooms. Teachers' views of games as supporting motivation, engagement, and out-of-school literacy and learning align with existing research on gaming (Gee, 2007; Stufft & von Gillern, 2021). Thus, the results presented here show that, despite the lack of easily accessible professional knowledge and resources related to the inclusion of video games in literacy curricula (Nash, 2022), teachers have been able to develop accurate conceptions regarding their potential as learning resources (Pelletier, 2009). The disconnect reported here between teachers' generally positive views of the potential learning applications of gaming and the hesitation related to games in classrooms suggests the need for the development of teacher education regarding gaming in classroom contexts and further research related to the kinds of games-based learning teachers may be considering as they consider their potential for classroom use. In the following section, we turn to further considerations regarding directions for future research and discuss the limitations of the present study.

Future research exploring teachers' perceptions of video games for literacy instruction and future research focused on the use of video games in classroom spaces can build upon limitations of this study. The 328 elementary literacy teacher participants who completed the survey all live and teach in the Midwestern United States. Future research should include the perceptions of teachers in other regions of the United States and also across other countries. It is important for future researchers to investigate the views and experiences of teachers across different geographical areas regarding the use of video games.

While respondents from rural, suburban, and urban schools participated in this study, the majority of participants were from rural or suburban settings, with approximately 15% of respondents from urban settings. Future research should continue to investigate the perceptions and practices of literacy teachers from different school settings, including urban schools. It may be valuable to consider the different resources, support, and training available to teachers in different school settings as relates to technology integration and the use of technology (including video games) in classroom spaces.

The majority of respondents in this study identified as female. Future research should continue to explore the ways that teachers' perceptions of video games relate to individual identities, including gender and race (Russworm & Blackmon, 2020). While this study focused on teachers' perceptions of video games, future research should examine the impact of teachers' own video gameplay experiences/expertise on their use of video games in the classroom. It may be of value to consider ways to provide professional development, support, and/or modeling for in-service teachers regarding the use of video games to teach literacy in order to further explore the relationship between teachers' perceptions of teaching with video games and their own experiences with using video games and receiving support and/or training regarding ways to teach with video games.

6. Conclusion

Research illustrates that video games are effective for promoting learning across various content areas (Clark, Tanner-Smith, & Killingsworth, 2016), and the participants in this study generally believed that video games and game-based learning can be an effective tool for promoting student motivation, engagement, and learning. However, the participants had mixed feelings about using video games in literacy instruction and only 36.6% indicated they regularly use games in their English language arts instruction. Thus, there is a disconnect between the the research on game-based learning, teachers' general opinions on game-based learning, and their willingness and efforts to integrate game-based learning in their English language arts instruction. Given that only 14% of participants indicated they learned about game-based learning in their teacher preparation programs, it is critical that both in-service and preservice teachers learn about game-based learning including its efficacy as demonstrated in research as well as practical activities for implementation in both literacy and other content areas.

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